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AN IMPROVED MAINTENANCE MODEL FOR THE SIMULATION OF STRATEGIC AIRLIFT CAPABILITY

THESIS

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

By
Wayne P. Stanberry
Capt USAF
Graduate Strategic and Tactical Sciences

March 1982

Preface

This thesis is a direct result of the help, encouragement, and support of many people. To Mr. Tom Kowalsky of the Military Airlift Command (XPSR) and his staff, I owe a special debt of gratitude for their continuous support and technical advice. I must sincerely thank Colonel Christopher Shaw for the use of information from his dissertation, as well as Mr. Charles Begin of the Aeronautical Systems Division (ENESA), who was a lifesaver when he offered the use of his data tapes.

Lieutenant Colonel Tom Clark, my advisor, is well deserving of my thanks for his guidance and patience through the months of this effort. Last of all, as it has been for many months, I must think of my family. For Pat and the children, there are no words to express the value of your support and dedication. Your sacrifices have made this thesis possible, and it is as much yours as mine.

Wayne P. Stanberry

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Abstract

The subject of this thesis is modeling of the maintenance function in the strategic airlift system. The implicit assumptions of the universal maintenance man concept are investigated for applicability. A more detailed model of the maintenance function is developed using SLAM as the primary simulation language. Maintenance manning is modeled at the Air Force Specialty Code level, to allow the possibility of bottlenecks in manning requirements. Maintenance discrepancies are determined for major subsystems of the airlift aircraft, and distributions for repair times are estimated for each subsystem. Substituting the detailed model of maintenance for a model that uses universal maintenance men, subsequent runs of a simulation of the airlift system show the assumptions of the universal maintenance man concept to be invalid. Additionally, in a simulation using aggregate bases, maintenance manning is not a significant factor.

AN IMPROVED MAINTENANCE MODEL FOR THE
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I Introduction

Background

Strategic airlift is the fastest method to transport men and equipment between theaters of operations. "It is a vital part of the balanced mobility force essential to the attainment of national objectives" (Ref 1:1). The defense of Europe and the North Atlantic Treaty Organization (NATO) allies is one of our primary national objectives, but recent increases in Soviet ground and air forces (Ref 5:100) have made this task more difficult. Our policy of forward defense (Ref 5:98) requires the forces in Europe to hold the Warsaw Pact until reinforcements arrive from the United States. Consequently, the primary objective of the United States Air Force mobility program is to be able, by 1982, to double the American divisions in Europe and increase the number of tactical fighter squadrons by 30 percent, in about ten days (Ref 5:207).

In order to plan defensive tactics, field commanders must know the capabilities of strategic airlift, the primary source of short-term resupply and reinforcement. The transportation feasibility study, as directed by the Joint Strategic Capabilities Plan (Ref 6), usually determines the tactical options of the field commander. To meet the requirements of the planning process, the Military Airlift Command (MAC) has tasked the DCS/Operations Plans "to maintain a simulation capability to evaluate airlift performance and capability in various scenarios" (Ref 11:182). In response to this tasking, the Operations Research Division at MAC, XPSR, has developed an extremely large simulation of the airlift system, M-14.

The M-14 simulation models the airlift system as a network of over 400 bases, through which aircraft, aircrews, and cargo flow. Complex control mechanisms monitor such items as crew duty time, crew rest times and facilities, and cargo load generation. Details of numbers of parking places, taxi times, and servicing capabilities are kept for each base in the system. Aircraft flying times are followed so inspections and unscheduled maintenance tasks can be accomplished by the maintenance force (Ref 9). This amount of detail represents a monumental simulation effort which has resulted in a very large model. There is one area, however, where the amount of detail may not be sufficient to capture the effect on the system.

M-14 uses what is commonly known as universal maintenance men. No distinction is made with regard to specialty skills among the maintenance force. All maintenance personnel are lumped into a pool and assigned from that pool. This is a common approach in modeling the maintenance function, because it simplifies the complex structure of specialty code manning. Because of the simplification, universal maintenance men are also used in smaller models, such as Holck and Ticknor's thesis effort, modeling the reinforcement of Europe (Ref 8). However, Holck and Ticknor noted that only 65 percent of their maintenance force was ever used at one time, so there were never any delays due to maintenance manning. They hypothesized that this did not represent reality and suggested that further work be done in the analysis of the maintenance area (Ref 8:78).

Implicit Assumptions

The use of universal maintenance men implies several assumptions concerning the nature of the airlift system. On face value, it assumes that any maintenance man can fix any discrepancy on an aircraft. With the complexity of modern aircraft, and by the very nature of the specialized training given to the maintenance force, this assumption cannot represent reality. To be acceptable, the use of universal maintenance men must make some other implicit assumptions. First, it assumes that the total number of discrepancies will always be distributed among the aircraft subsystems in exact proportion to the percentage of the maintenance force that is capable of fixing those subsystems. For example, if five percent of the maintenance force consists of the technicians that spcialize in radar, for any given period of time, exactly five percent of all maintenance discrepancies will have to be on radars. Under this assumption, no aircraft can be delayed due to lack of maintenance personnel, until the entire maintenance force is busy.

The second implicit assumption, stemming from the fact that there will be no delays until the entire maintenance force is busy, is that a very high percentage of the maintenance force <u>will</u> be used. The only effect that maintenance manning could have, in a simulation of strategic airlift capability, is to cause delays while aircraft wait for maintenance men. Thus, if maintenance manning is modeled, delays must be expected. Since those delays only occur after 100 percent utilization of the maintenance force, that high rate of utilization must be expected.

Problem Statement

The implicit assumptions associated with the use of universal maintenance men do not seem to be realistic. Maintenance discrepancies are not likely to occur in exact proportion to the manning levels of the appropriate maintenance specialists. Additionally, it may not be possible to obtain 100 percent utilization of the maintenance force. If these assumptions are not valid, the results from a simulation that employs universal maintenance men, as Holck and Ticknor suggested, may not be representative of the actual maintenance system. Similarly, the effect of maintenance manning on strategic airlift capability may also be misinterpreted.

Purpose and Objectives

The purpose of this thesis is to test the implicit assumptions of the universal maintenance man concept and to determine the usefulness of the application of universal maintenance men in simulations of strategic airlift capability. In order to accomplish this purpose, the following objectives were established:

1. Develop a realistic model of the maintenance system, with emphasis on a detailed manning structure.
2. Determine whether maintenance discrepancies among subsystems occur in proportion to the numbers of specialists capable of repairing them.
3. Determine whether 100 percent utilization of the maintenance force is feasible.
4. Determine whether maintenance manning has a significant effect on airlift capability.

Scope and Limitations

This study deals exclusively with the issue of maintenance manning within a simulation of strategic airlift capability. This model is based on detailed modeling of maintenance manning, rather than the use of universal maintenance men, and is intended only to show the differences in the two approaches. The results of this study or the mathematical methods of modeling this system may not be applicable to other types of aircraft or other roles. Also, the data, used in this study, was collected during peacetime and may not be representative of the actual wartime figures. However, the general relationships, with which this thesis deals, should apply to both scenarios. Finally, the model developed in this thesis is tailored for inclusion in a simulation of a particular wartime scenario, and it may require expansion or specific tailoring to other scenarios.

Methodology

The first objective of this thesis is the development of a credible model of the maintenance system. The model must reflect the processes and interactions that occur between maintenance discrepancies and the maintenance force in the actual system. Stochastic variables, such as the number of discrepancies observed, the probability of requiring off-base supply, the duration of repair times, and the probability of requiring certain specialists, make an analytical approach difficult. Alternately, simulation offers a methodology that handles stochastic variables, allows experimentation with a system that is too complex for direct experimentation, and serves as a tool for the analysis of the behavior of a system (Ref 20:10,11). Therefore, this study employs a simulation model as the primary tool for investigation of the maintenance system.

The methodology for the development of a simulation model is encompassed in the systems science paradigm

(Ref 19:295), and the format of this study parallels that paradigm. The first step in the paradigm is to conceptualize the logic of the interactions of the elements of the system (Ref 19:288). This conceptualization requires an understanding of the system and how it operates, both internally and with its environment. The second step, analysis and measurement, requires the quantification of the interactive processes and the means of measurement (Ref 19:299-301). This portion includes the analysis of input data and the development of a mathematical model of the system. Finally, the third step involves the conversion of the mathematical model into a computer model (Ref 19:302). Again, the computerization process must retain the logic of the flow through the system, as conceptualized in the first step.

This three-step process for development of the simulation model is also iterative, in that analysis of the computer model often leads to reconceptualization of the system, and the process starts over (Ref 19:302). The three steps, presented in Chapters III, IV, and V, represent the final iteration of the paradigm in this study of the maintenance system. Together, they form the process by which a representative computer model of the maintenance system was developed. However, a model is of no use unless its validity can be established. Since validation is part of each step in development of the model, the approach to validation is discussed in Chapter II, prior to the development of the model. With this representative model, the analysis required to meet the other objectives of this thesis was accomplished.

Determining the validity of the assumptions of the universal maintenance man concept requires analysis of the internal behavior of the maintenance system. Likewise, determining the significance of maintenance manning requires an analysis of the maintenance system in operation, inside the larger airlift system. The role of experimental design is to plan both the form of the computer model, for partial analysis of the behavior of the system, and the final strategic and tactical plans for execution of an experiment (Ref 20: 149). The experimental design for this thesis accomplishes both of these. The model was designed to produce useable statistics on the utilization of the maintenance force, and the experiments were designed specifically to test the levels of manning utilization and the significance of maintenance manning on the airlift system. Finally, the Statistical Package for the Social Sciences (SPSS) (Ref 14) was used to do the statistical analysis of the results of those experiments.

Overview

The remainder of this thesis details the process by which the study was conducted, presents the findings, and lists the conclusions and recommendations. Chapter II explains the validation process and the particular methods of validation used in this study. As previously mentioned, Chapters III, IV, and V represent the process of developing the simulation model. Chapter III presents the maintenance system and conceptualizes the processes within the system. Chapter IV details the methods used to develop a mathematical model of the system and determine its inputs. Finally, Chapter V shows the computerization of the mathematical model and the verification of the computer model. Chapter VI explains the experimental design used to analyze the maintenance system and discusses the results of those experiments. Chapter VII lists the conclusions and recommendations for both application of these results and further research.

II Validation

Introduction

If a simulation model is to be used as a tool for the investigation of a system, as is the case in this thesis, the validity of that tool must be established. Although the definition of validation is somewhat elusive, most authors include three concepts in their definitions. First, the purpose of the model must be accomplished. Second, the fact that any inferences drawn from the model are applicable to the actual system must be established. Last, but most important, validation is a process of building confidence in the model and its outputs. Naturally, since this is a continuing process, we can never attain absolute validity (Ref 17). Because validation encompasses the entire process of modeling, this chapter on validation is presented to explain the validation methods in this thesis, prior to the chapters on model development.

Current Philosophy

The process orientation of validation is supported by the general acceptance of Naylor and Finger's multi-stage approach to validation (Ref 13:B-92). In order to build confidence in the model, throughout the simulation process, the idea of looking back, after the simulation is finished, to try to validate what was done, must be discarded. Averill Law suggests that model development and validation must be done hand in hand, throughout the course of the simulation study (Ref 10:338). Additionally, Sargent (Ref 17) and Van Horn (Ref 25) agree that documentation, throughout the study, is the key to confidence building.

The multi-stage approach encompasses all three of the underlying philosophies of validation. The rationalist view, based on synthetic a priori or unquestionable truths, suggests that the validity of a model is based on the unquestionable system of logic inherent in the model. The empiricist suggests that all assumptions and hypotheses must be empirically verified, and positive economics maintains that the output, or predictive ability of the model, is all important (Ref 13: B-93 to B-95 and 20:212-214). Combining all of these, the most rigorous method of validation includes demonstration of clear logic underlying the model and its assumptions, mathematical verification of all inputs and processes within the model, and comparison of outputs with the actual system. Thus, validation begins with the conceptual stage of development and continues through the entire process of model building.

Complete validation, as described above, should be a goal of any study, however, not all models can be completely validated. Note that complete validation does not infer absolute validity, but only the completion of all the phases of the validation process. If the system being modeled is only a proposed system, or the scenario being modeled is expected in the future, no actual system outputs are available for comparison to model outputs. Positive economics implies that this situation cannot be validated, but a multistage approach still leaves two stages for partial validation. If the logic of the model and mathematical processes are shown to be valid, confidence in the model is increased and a higher level of validity is achieved.

Methods Used

The model, developed in this thesis, simulates a large and complex system that is not amenable to direct experimentation. Additionally, only a portion of the actual system is directly incorporated into the model. Also, to experiment with the model, it is included in a simulation of a future scenario. For these reasons, comparison of model outputs to actual system outputs is not feasible. Therefore, validation of this model relies heavily on the acceptance of its logic and the verification of its inputs. Additionally, the primary purpose of this model is to investigate the nature of the processes that occur within the maintenance system, and not to observe specific output data. Since validation applies only to the intended purpose of the model, the emphasis of validation is placed on the proper representation of those inner processes in this model.

Since the validity of this model depends on the acceptability of its logic and inputs, every effort has been made to explain each step of model development in detail.

The logic employed has been kept as straightforward as possible, while allowing enough detail and complexity to capture the true nature of the system. The initial test of the validity of this logic is its acceptance by Lieutenant Colonel Thomas C. Clark, the advisor for this thesis. His extensive experience, in both simulation modeling and the aircraft maintenance field, provides the basis for an expert judgement of this modeling effort. The final judgement, of course, is left to the individual reader of this thesis.

The inputs and mathematical processes, developed in Chapter IV, have been individually validated as much as possible. Where applicable, previous validation of individual inputs is cited. Statistical methods and justification for these methods are explained, and references are given for each method. No credit is taken for an exhaustive study of each input; however, the limitations and additional considerations are discussed for each input. Also, the possible effect of these limitations, on the results of this study, are considered.

Besides the steps described above, additional confidence can be gained by ensuring that the logic, developed in Chapters III and IV, is properly translated into the computer program, and the program runs as expected (Ref 7: 12-19). This process is commonly referred to as the verification of the model, and the verification procedures are discussed at the end of Chapter V. Taken as a whole, the validation attempts should support the validity of this model for its intended purpose.

III Conceptualization

Introduction

In order to accurately model any system, the nature of the system must be understood, and the interactions of that system with its environment must be analyzed. This conceptualization process begins at a highly abstract level and incrementally decreases in abstraction as details are added to the conceptual model (Ref 19:290). The approach taken here follows the same pattern. The maintenance system is analyzed and a conceptual model is developed in an increasingly complex form.

Maintenance System

The maintenance system is actually a subset of the complete airlift system, and it acts as an input-output system. In the most basic form, maintenance can be considered a black box that gets an input from the airlift system. This input is an aircraft that has completed a sortie and, in the process, may have generated some maintenance discrepancies. The black box holds the aircraft for a given period of time and then returns the aircraft to the airlift system when the discrepancies are fixed (see Figure 1). If the time delay, while in maintenance, could be determined without any more detail than this, modeling this system would be a simple matter of determining the longest repair time for any discrepancy. However, there are several limiting factors not

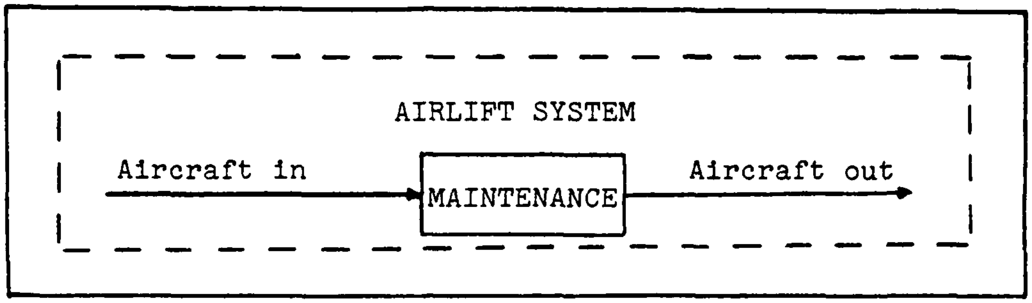

Fig 1. Black Box Model of Maintenance

yet accounted for. Of particular interest, in this study, is the possibility that the aircraft may incur additional waiting time due to a lack of qualified maintenance personnel.

Additional Factors

If the availability of maintenance personnel is considered, spare parts must also be included. The availability of spare parts determines whether personnel remain at work, or are released until parts can be acquired. A new logic flow (see Figure 2) is generated for this case. When an aircraft enters maintenance, a determination of the number of discrepancies is made. If none, the aircraft is mission-ready and departs maintenance. If maintenance is required, personnel are assigned to begin work on the discrepancies. If spare parts are required and are immediately available, or, if no parts are required, work continues until the aircraft is fixed. If parts are required, but are not available, the parts are ordered and the personnel freed until the parts

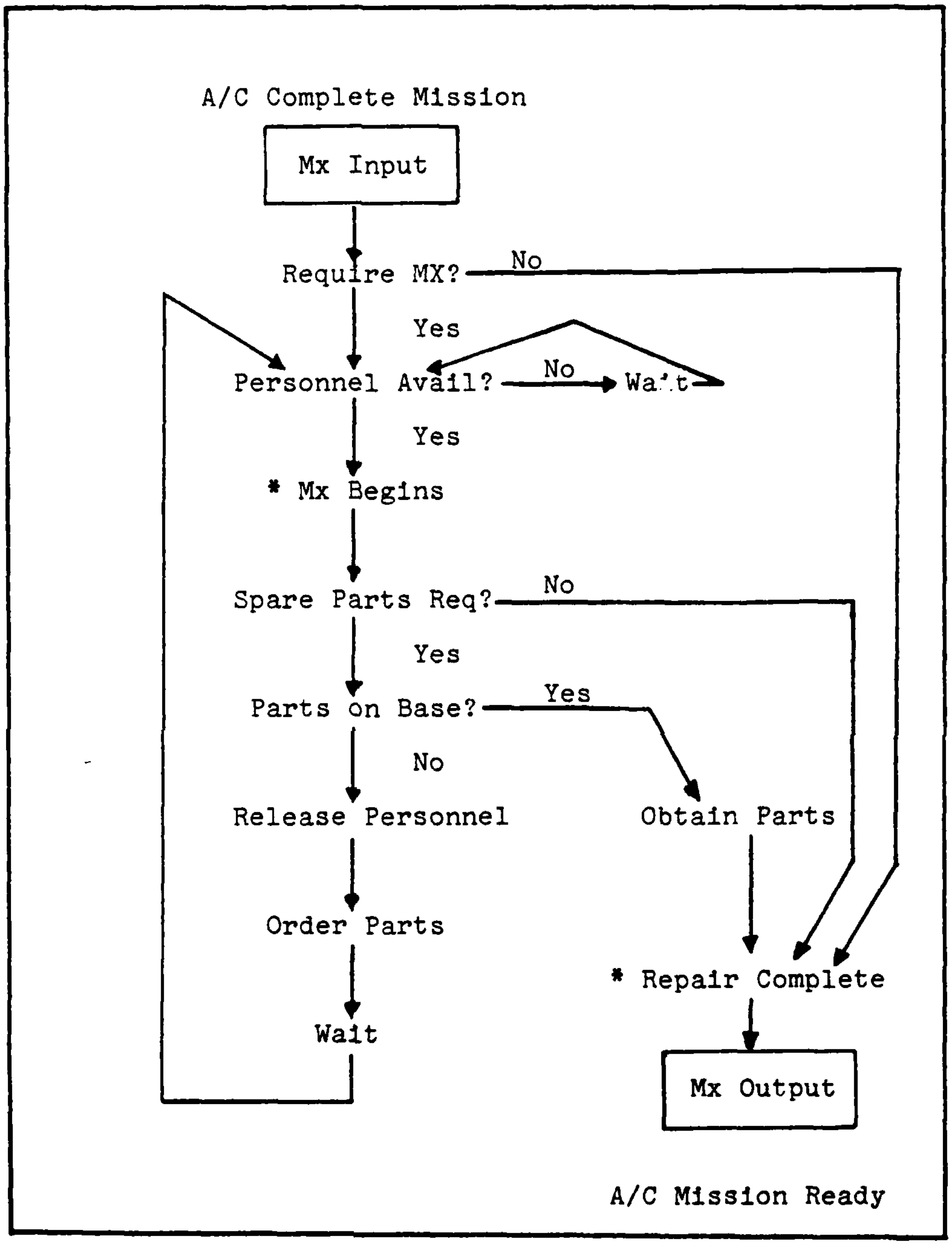

Fig 2. Maintenance Logic Structure

arrive. At that time, personnel are again allocated to the aircraft to finish the job.

This is the level of conceptualization that the universal maintenance men are used. One resource, consisting of all maintenance men, is used, with no differentiation of specialty skills. Additionally, at this level, many other factors are assumed to be insignificant. The availability of maintenance facilities and weather are two examples that have some impact on the amount of time spent in maintenance. However, in keeping with the idea that a model should be designed around the questions to be answered rather than imitate the real system exactly (Ref 20:27), these factors can be discounted. Without facilities and with inclement weather, the jobs could still be accomplished, perhaps requiring more time than normal. Since the emphasis of this study is not to determine exact maintenance times, but to investigate the effects of manning on that time, the inclusion of these factors would complicate the model unnecessarily.

Causal Structure

At this point, the conceptual model is still relatively simple. As the number of aircraft, or the utilization rate of those aircraft, increases, more maintenance discrepancies are encountered. These discrepancies require more personnel and spare parts, and either of these can become a limiting factor. If the spare parts are depleted, aircraft must wait until parts are made available from off-base sources. If the number of personnel available is exceeded, aircraft must wait for other work to be completed and personnel freed. The end result of either of these circumstances is extended time in maintenance and a decrease in aircraft utilization. Thus, maintenance acts as a self-regulating feedback loop (Ref 20: 63). The effect of this loop, on the airlift system, is to control the number of aircraft flying in the system.

Subsystems and Specialty Codes

In order to analyze the distribution of maintenance requirements among the specialists, one more level of complexity must be added to the conceptual model. In the actual maintenance system, the maintenance force is divided into groups of specialists that receive technical training in the maintenance of particular types of equipment. These groups are designated by Air Force Specialty Codes(AFSCs) (Ref 2) and are essentially non-interchangeable. Thus, there are actually a group of AFSCs, each of which could be a limiting factor. Additionally, each subsystem on an aircraft can require a different AFSC or combination of AFSCs for repair. For example, a discrepancy in the landing gear subsystem can require specialists in electrical systems, hydraulics, pneumatics, or the physical hardware of the gear itself.

At this level of complexity, an incoming aircraft can be depicted as a simultaneous input of several subsystems to the maintenance function (see Figure 3). Each of these subsystems goes through a separate process, using the logic

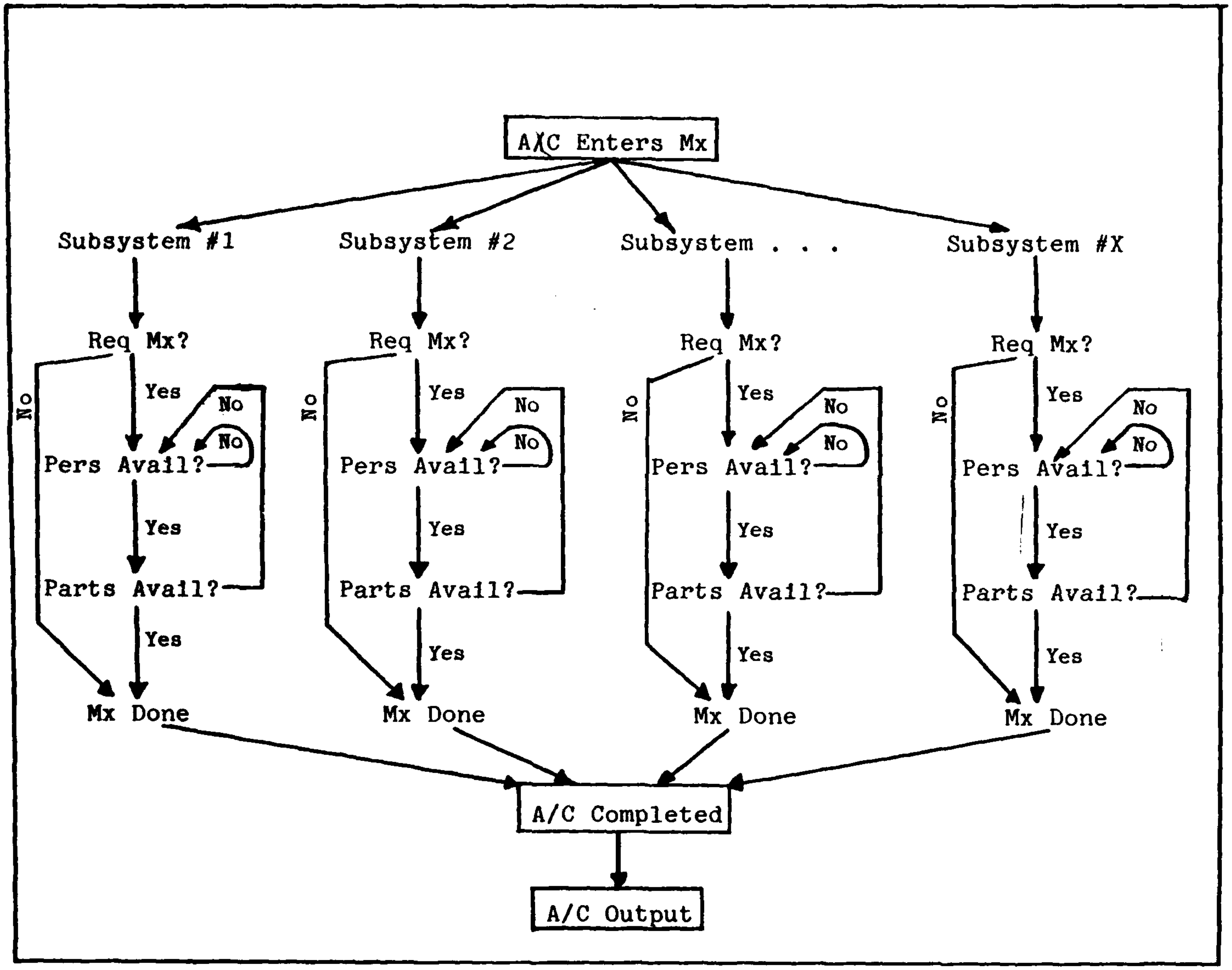

Fig 3. Subsystem Approach

shown in Figure 2, where they compete for the personnel from the appropriate AFSCs. After all of the subsystems have completed their maintenance, the aircraft is aggregated as a whole entity and output from the maintenance function.

Finally, at this level of complexity, the proportion of discrepancies requiring each maintenance specialist can be observed, so the assumptions of the universal maintenance man concept can be tested. Therefore, no further conceptualization is necessary, and the logic depicted in Figure 3 will be the logic that is passed to the next phase for analysis and measurement.

IV Analysis and Measurement

Introduction

Once the logic of the conceptual model has been developed, that logic must be converted to a mathematical model which can be computerized. In order to develop the mathematical model, each element and process in the conceptual model must be quantified. This chapter deals with the analysis of those elements and processes and the methods used to quantify them. From Figure 3 in Chapter III, the logic of the conceptual model requires a determination of:

1. Which subsystem must be included in the model?
2. How many discrepancies will be encountered by each subsystem?
3. Which AFSCs are required to repair those discrepancies?
4. How long does that repair take?
5. Are spare parts required for each discrepancy?
6. What delay, if any, will be incurred while waiting for spare parts?

The answers to some of these questions are dependent on the scenario for which the model will be used. For instance, the difference between normal operations and a wartime scenario might make a large difference in the number of subsystems required. In wartime, only the critical subsystems that might prevent safe flight would have to be repaired. Because of this scenario dependence, the model will be developed for a particular scenario. Holck and Ticknor's simulation of the reinforcement of Europe (Ref 8) was chosen as an example of the use of the maintenance model developed in this thesis. The reasons for this choice will be explained in Chapter VI, but any simulation of airlift capability could use this approach to modeling the maintenance area.

Holck and Ticknor simulated a wartime scenario, using aggregate bases. Thus, the model, as developed in this thesis, will reflect that scenario. Only certain subsystems will be considered, and the entire maintenance force will be modeled as if it was positioned at one aggregate base where maintenance takes place. As will be seen in Chapter VII, this limited application did not prevent the model from showing the processes of interest in this thesis. The remainder of this section will detail the methods used to quantify each of the questions previously listed.

<u>Determination of Discrepancies Encountered</u>

As previously mentioned, most simulations use universal maintenance men, so there has been no reason to differentiate between discrepancies encountered in different subsystems. Thus, no distributions of maintenance discrepancies were available, at the subsystem level. However, Colonel Christopher Shaw, Chief of the Mobility Branch, Studies and Analysis, Headquarters USAF, has derived a set of equations to give the expected number of failures for each subsystem (Ref 21). His research will be discussed, followed by the method used to convert his expected failures to the actual number of failures encountered.

Colonel Shaw's research was done, primarily, to determine the number of spare parts required to support the airlift fleet. His data deals exclusively with maintenance actions that require removal and replacement of a part, or removal, repair, and replacement. These actions represent the major part of the time consuming maintenance jobs, and they include all of the jobs that require spare parts. Thus, his data appears to be applicable to the purpose of this model.

Most simulations use a constant number of maintenance actions per flying hour, but this infers that there is a linear relationship between length of time flown and the number of maintenance discrepancies (see Figure 4). In other words, given a constant failure rate per flying hour, three

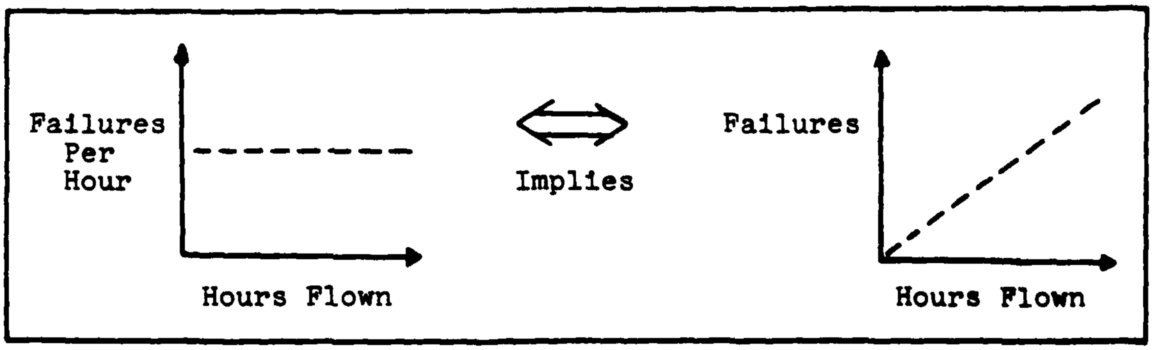

Fig 4. Inference of Linearity

times as many discrepancies can be expected on a three hour flight as a one hour flight. This does not appear to fit reality, since most crewmembers will hypothesize that the majority of failures occur during the takeoff or landing phases of flight, and relatively few failures occur during cruise.

Colonel Shaw hypothesizes that most failures are cycle related because of thermal stress. As equipment is turned on and off, the associated heating and cooling is responsible for failures. Also, cycling of systems, such as the landing gear and flaps, puts stress on the individual parts and results in their failure. Conversely, during cruise, termperatures are relatively constant and systems like the gear and flaps are not being cycled. As a result, there is a much lower failure rate during the cruise phase than in the high stress phases of takeoff and landing (Ref 21). Thus, a long sortie that spends many hours at cruise would experience less failures per hour than a short sortie (see Figure 5).

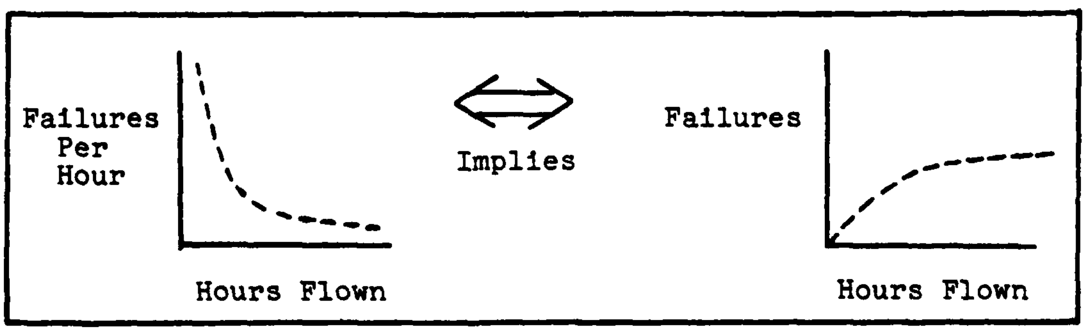

Fig 5. Non-Linear Hypothesis

To validate his hypothesis, Colonel Shaw was the study director for Saber Sustainer, a study of the relationship between failure rates and length of sorties. The study concentrated on major subsystems of many different aircraft, including the C-5. The results for the C-5 were representative of all the aircraft and will be presented as an example of a strategic airlift aircraft. A baseline of 12.5 hours per day utilization rate was established and sortie lengths of 5 and 10 hours were investigated. The results were very much as Shaw predicted:

5 hour sortie = 23.3 failures per day

10 hour sortie = 14.3 failures per day

OR

2 times sortie length = 39% fewer failures per day

In addition, approximately 75% of all failures occur during takeoff and landing (Ref 22). Not surprisingly, this led to a graph of failures per flight hour against sortie length (see Figure 6) that is very similar to the hypothesized non-linear model.

The end result of Shaw's study was to derive a simple equation for the expected number of failures which reflected the non-linear nature of the failure rate. Since all sorties experience the high failure rates of takeoff and landing, those portions of the flight could be approximated by a constant expected number of failures. Then, the remaining

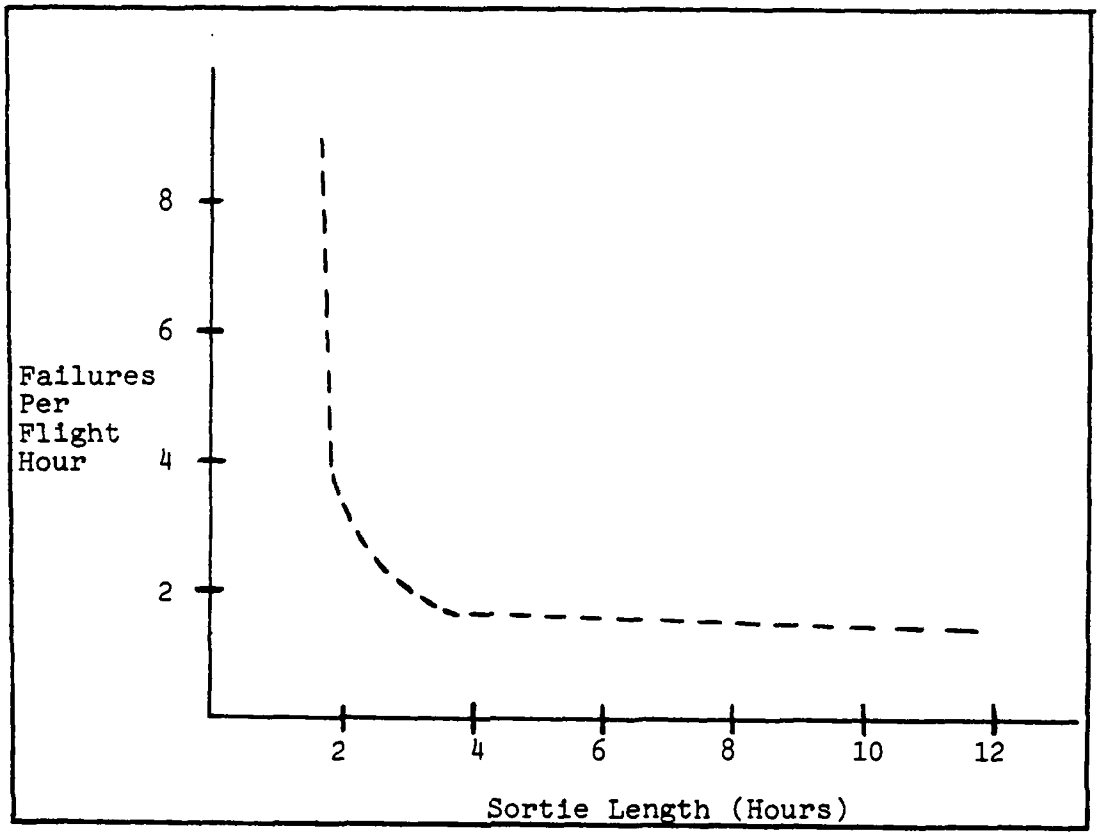

Fig 6. Actual Data for the C-5

portion of the flight could be approximated by the relatively constant rate of failure at cruise. Using regression analysis, Shaw derived the expected number of failures, as a function of sortie length, in the familiar form (Ref 21):

$$Y = A + BX$$

where,

Y = Expected number of failures

A = Constant due to start and stop

B = Adjusted failure rate

X = Sortie length in hours

The accuracy of these equations was tested by direct data gathering in the field. Selected aircraft were followed and specific maintenance discrepancies were tabulated. The results showed an excellent correlation between failures predicted by the equations and those actually encountered (Ref 22). Thus, Shaw's non-linear hypothesis was supported by the Saber Sustainer Study, and his resulting equations appear to be consistent.

For the purpose of this thesis, Shaw's study results in a table of parameters, by aircraft type, which can be inserted into the equation previously given. Table I lists the parameters for the C-5, and Table II lists the parameters for the C-141. In both tables, parameters are listed for each major subsystem, and the two-digit Work Unit Codes (WUC) (Ref 23 and 24) that identify those subsystems are shown. With these parameters and the sortie length, the expected number of failures in any subsystem can be determined. However, this expected number of failures is an average number that could be expected over a series of flights of the same sortie length, and is usually a non-integer number.

In this model, the actual number of discrepancies encountered, for any given subsystem, must be an integer number. In the actual system, it is impossible to see one and a half failures in a subsystem. For this reason, an

TABLE I

Shaw's Parameters for the C-5

WUC	Subsystem	A	B
11	Airframe	.373	.012
12	Cockpit & Fuselage	.194	.028
13	Landing Gear	.614	.035
14	Flight Controls	.074	.018
23	TF-39 Turbofan Engine	.253	.096
24	Auxiliary Power Plant	.064	.018
41	Air Conditioning & Press.	.080	.027
42	Electrical Power Supply	.118	.030
44	Lighting System	.771	.375
45	Hydraulics and Pneumatics	.151	.048
46	Fuel System	.111	.012
47	Oxygen System	.041	.005
49	Misc. Utilities	.061	.020
51	Instruments	.122	.049
52	Autopilot	.067	.035
55	Malfunction Analysis Equip.	.262	.085
61	HF Communications	.013	.021
63	UHF Communications	.024	.004
64	Interphone	.016	.010
65	IFF	.003	.004
71	Radio Navigation	.060	.016
72	Radar Navigation	.138	.063

TABLE II

Shaw's Parameters for the C-141

WUC	Subsystem	A	B
11	Airframe	.0336	.0604
12	Fuselage Compartments	.0443	.0451
13	Landing Gear	.0317	.0508
14	Flight Controls	.0129	.0278
23	TF-33 Engine	.0524	.0772
24	Auxiliary Power Plant	.0048	.0051
41	Air Conditioning-Press.	.0106	.0190
42	Electrical Power Supply	.0065	.0070
44	Lighting Systems	.0288	.0334
45	Hydraulic Power Supply	.0097	.0292
46	Fuel System	.0120	.0080
49	Misc. Utilities	.0092	.0120
51	Instruments	.0218	.0181
52	Automatic Flight Controls	.0276	.0253
62	VHF Communications	.0050	.0051
63	UHF Communications	.0180	.0033
64	Interphone	.0007	.0152
65	IFF	.0021	.0049
71	Radio Navigation Systems	.0486	.0135
72	Radar Navigation Systems	.0709	.0266
73	Station Keeping (INS)	.0138	.0120

extension to Shaw's work had to be made. Since time to failure of individual parts is often exponentially distributed (Ref 12:8), the numbers of failures would be expected to be Poisson distributed (Ref 16:31). Therefore, the actual number of discrepancies encountered should be Poisson distributed, with the mean of the distribution given by Shaw's equation. This assumption does not invalidate the regression procedure, since a normal distribution of the errors is not required to estimate the regression line (Ref 26:282-285). Thus, the number of discrepancies for any given subsystem is obtained as a random variate from a Poisson distribution. The mean of that distribution is equal to the expected number of discrepancies from Shaw's equation. An example of this process is shown in Figure 7.

Assume: X = Sortie Length = 10 hours
Subsystem = TF-39 Engine
Aircraft = C-5

From Table I: A = .253
B = .096

Calculation of Expected Number of Discrepancies (Y):

$$Y = A + BX$$
$$Y = .253 + .096(10)$$
$$Y = 1.213$$

Actual Number of Discrepancies =

Random Variate Drawn From a Poisson Distribution With a Mean of 1.213.

Actual Number = 2

Fig 7. Calculation of Number of Discrepancies

Subsystems in the Model

Since this model is designed for strategic airlift, only the C-5 and C-141 aircraft are considered. Also, the use of this model would primarily be in a simulation to determine airlift capability under some wartime scenario. Therefore, only those subsystems likely to include items on the wartime Minimum Essential Subsystems List (MESL) are considered. Of those, only the subsystems with relatively high probabilities of failure, as determined from Shaw's equations, were included in the model. The subsystems used in the model are shown in Table III, with the two-digit work unit code that identifies each system (Ref 23 and 24).

TABLE III

Subsystems Included in the Model

	Work Unit Code	Subsystem
1.	11 (both A/C)	Airframe
2.	13 (both A/C)	Landing Gear
3.	14 (both A/C)	Flight Controls
4.	23 (both A/C)	Engine
5.	42 (both A/C)	Electrical System
6.	45 (both A/C)	Hydraulics
7.	46 (both A/C)	Fuel System
8.	51 (both A/C)	Instruments
9.	72 (both A/C)	Radar
10.	55 (C-5)	Malfunction Analysis
11.	73 (C-141)	Inertial Navigation

Repair Times

Most simulations use a single distribution from which they draw all times to repair. Because there may be significant differences between subsystems, an attempt was made to estimate the distributions for each subsystem in the model. A data base, separable by distinct subsystem, was required to estimate these distributions. Initially the latest six-month maintenance data tapes from Charleston (C-141s) and Dover (C-5s) were requested from MAC Headquarters. These tapes report the maintenance actions as individual observations, and represent the raw, non-aggregated data required to accurately determine the distributions. Unfortunately, due to tape drive problems, those tapes were not available.

As a secondary source, Mr. Charles Begin, ASD/ENESA, was contacted, and he provided data tapes (Ref 4) that had been acquired from MAC earlier. One tape covered the period, January-June 1980, for Dover AFB. It represented 2,214 sorties and 11,652 flying hours for the C-5. The other tape covered the period, July 1979-June 1980, for Charleston AFB. It represented 17,953 sorties and 62,773 flying hours for the C-141. These tapes are base-level, raw maintenance data, as expected. However, the sheer size of the maintenance data file, 1200 record blocks for one tape, represented a major obstacle to useful manipulation. Additionally, the maintenance reporting procedures make the data difficult to use. Discontinuities in time reporting, unfinished transactions, and multiple inputs for a single discrepancy are only a few of the inherent problems.

In order to get useful information from the tapes, a different version of the basic data tapes was used, the A-1 tape. The A-1 is a condensed version of the raw data tapes that has been organized by sorting the raw data tapes with the Consolidated Data Extraction Program (CDEP). The CDEP converts the codes on the data tapes to standard AFSCs and sorts the records by aircraft type. On a second pass through the data, it consolidates information to eliminate multiple records on the same job control number. This combines off-equipment maintenance with on-equipment removals, compacts times for overlapping or discontinuous work when several AFSCs are working the same job, and adjusts the crew size for overlapping times worked by different crews. On the third pass, the data is arranged by work unit code numbers, formatted in a job-by-job analysis, and any entries that required the same combination of AFSCs to work on a subsystem are aggregated to provide an average time and crew size for that type of entry (Ref 3).

The A-1 tape is formatted for easy access to information. Its principle benefit is that all jobs are reported as continuous actions, with all unnecessary delays and discontinuities eliminated. Also, multiple entries are combined and listed as multiple AFSCs working on the same job. Unfortunately, the aggregation of all jobs using the same AFSCs tends to obscure the nature of the underlying distribution of repair times. This aggregation lumps groups of data points at their mean value and reports "X" number of occurrences of the same maintenance time. The result of this grouping is an inability to test the data against specific distributions. Statistical tests, such as the Chi-Square test, rely on relative frequencies of occurrences to test distributions (Ref 15:70), but the grouping of data points in the A-1 tape destroys those relative frequencies. Therefore, some other method of estimating the distributions had to be used.

In Techniques for Efficient Monte Carlo Simulation, the Defense Technical Information Center (DTIC) document on the selection of probability distributions (Ref 12:7), equal emphasis is placed on quantitative and qualitative information. The qualitative aspect includes the extent of *a priori* knowledge about the process under consideration. In that same document, the authors state that maintainability theory provides a strong likelihood that repair times would be lognormal or gamma distributed (Ref 12:8). To support this hypothesis, a graphical analysis of the characteristic shapes of the distribution of maintenance times was performed. The observations for each subsystem were input to the Statistical Package for the Social Sciences (SPSS) Subprogram Frequencies (Ref 14:194), to get a plot of the frequency distribution in a histogram. Two representative plots of these frequencies are shown in Figures 8 and 9. Work Unit Code

```
CODE
    I
 1. *********************** (449)
    I
    I
 2. **************************************** (785)
    I
    I
 3. ************* (242)
    I
    I
 4. ******* (128)
    I
    I
 5. **** (59)
    I
    I
 6. ** (15)
    I
    I
 7. * (6)
    I
    I
 8. ** (11)
    I
    I
 9. * (4)
    I
    I
10. ** (17)
    I
    I
    I.........I.........I.........I.........I.........I
    0        200       400       600       800       1000
    FREQUENCY
```

Fig 8. Frequencies of Repair Times, WUC 14

```
CODE
     I
 1.  *************************************** (146)
     I
     I
 2.  ******************************* (120)
     I
     I
 3.  ************************** (99)
     I
     I
 4.  ************************* (95)
     I
     I
 5.  ********* (30)
     I
     I
 6.  ** (2)
     I
     I
 7.  ** (5)
     I
     I
 8.  ** (5)
     I
     I
 9.  ** (2)
     I
     I
10.  ******* (22)
     I
     I
     I.........I.........I.........I.........I.........I
     0         40        80        120       160       200
     FREQUENCY
```

Fig 9. Frequencies of Repair Times, WUC 11

(WUC) 23, in Figure 8, represents the time to repair engine malfunctions for C-5s, and it displays the typical shape that could be either gamma or lognormal. WUC 11, in Figure 9, represents C-5 airframe repair times, and it appears to approach an exponential curve, a special case of the gamma. Since the gamma distribution is more flexible, using shape parameters, it was selected as the representative distribution.

The mean and variance of the sample data were used as estimates for the mean and variance of the underlying distributions, and the following equations were used to estimate the gamma parameters (Ref 26:132):

$$\mu = \alpha\beta \quad \text{and} \quad \sigma^2 = \alpha\beta^2$$

Thus, each subsystem has its own distribution of repair times. All are gamma distributed, but the shape parameters are different for each subsystem. These are only estimates of the repair time distributions, based on estimates from the reported data and established knowledge of maintainability theory. However, they should be more representative of actual repair times than drawing from a single tabular distribution of historical repair times.

Specialty Codes Required

The A-1 data tapes (Ref 4) gave an excellent description of the AFSCs required for repair of each subsystem. A program was written to extract, by aircraft and subsystem, all of the AFSCs that had worked on each particular subsystem.

Also, the total number of times that each AFSC was required, divided by the total of all jobs on that subsystem, yielded the percentage of jobs that required each AFSC. The listing of the subsystems and required AFSCs, plus the percentage of jobs that required those AFSCs, is fairly extensive.

By disregarding any AFSC that did not account for at least 4.9 percent of the total jobs, only thirteen AFSCs were represented. The reason for dropping the lower percentage AFSCs is obvious. If they are only used to that small a degree, there is almost no chance that they could be a limiting factor in the manning scheme. Those AFSCs will not be modeled, but the jobs will be accomplished, as if there were an infinite number of those maintenance men available. Likewise, the 431P2 and 431X2 AFSCs were dropped from the model because their manning levels were so high, they could allocate a maintenance team to every aircraft in the MAC fleet. Also, these AFSCs are the flight line crew chiefs and the isochronal dock general aircraft maintenance men. Their specialties do not represent the specific type of maintenance of interest in this study, since they do very general maintenance tasks.

With the exclusion of these AFSCs only eleven AFSCs were of interest in the model. The percentage of total jobs, on each subsystem, requiring each AFSC is depicted in Table IV. These percentages do not add to 100 percent for each subsystem because of the jobs that will be done by AFSCs not modeled. Once the type of maintenance specialties required

TABLE IV

AFSCs Required for Repair

WUC	A/C	431R2	431W2	423X0	423X1	423X3	423X4	426X2	325X0	325X1	328X1	328X4
11	141	30.3%					34.0%					
	C-5	26.4%		5.1%			23.2%					
13	141		47.3%	14.5%			30.2%					
	C-5	4.7%	47.2%	7.8%			20.1%			7.4%		
14	141	25.4%		10.5%			22.8%		6.8%	15.6%		
	C-5	16.3%		12.7%			49.3%					
23	141							43.4%		38.9%		
	C-5							41.3%		33.0%		
42	141	7.8%		70.7%				5.1%	5.1%			
	C-5			57.6%				18.9%				
45	141						91.2%			6.5%		
	C-5				14.6%		72.0%			5.2%		
46	141					54.0%				39.2%		
	C-5			41.6%		20.9%				27.8%		
51	141									99.2%		
	C-5								27.7%	52.8%	11.8%	
72	141										99.2%	
	C-5										58.8%	40.0%
73	141										56.7%	43.1%
55	C-5							8.6%				87.2%

was determined, the next step was to determine the number of effective maintenance teams in each of those specialties.

Senior Master Sergeant George Scarborough (Ref 18) obtained all of the manning data used here. He has extensive experience working with the Logistics Composite Model (LCOM), and he has recently been working with the M-14 simulation. All of the figures, quoted here, are used as standard inputs to LCOM or are standard Air Force planning factors. As a baseline figure, the current manning authorizations for each AFSC were used. Throughout maintenance, only 75 to 80 percent of the authorized slots are currently manned. Optimistically, this study assumes that 80 percent of the authorizations are manned.

In order to use the manning in the model, the manning figures had to be converted to effective maintenance teams. The Air Force Maintenance and Supply Management Engineering Team estimates that 82 percent of available man-hours are effective, so this model used 82 percent of the available manning as productive manning. Then, the productive manning levels were divided into two shifts, and further divided into 2.5 men teams. The team size is an average of all the teams represented on the A-1 data tape. The final figure represents the number of effective teams that will be available at any given time. Table V shows the numbers and process used in deriving these teams.

TABLE V

Conversion of Manning Slots to Effective Teams

AFSC	Auth. Slots	Manned Slots	Prod. Slots	Men/ Shift	Teams
431R2	564	451	370	185	74
431W2	140	112	92	46	18
423X0	329	263	216	108	43
423X4	438	350	287	143	57
426X2	1471	1177	965	482	193
423X1	347	278	228	114	46
423X3	215	172	141	70	28
325X1	341	273	224	112	45
325X0	283	226	186	93	37
328X1	372	298	244	122	49
328X4	275	220	180	90	36
	(slots)	(x.8)	(x.82)	(x.5)	(x.4)

Supply Requirements

Unlike the number of discrepancies and repair times, the time required for off-base supply has been investigated previously. Holck and Ticknor used data, supplied by MAC, to derive a tabular distribution for supply times (Ref 8:38). This is a single distribution for all spare parts, and it may or may not be accurate for a detailed study of the supply function. However, this study concentrates solely on the effects of manning. Since the probability of requiring spare parts, and the associated supply delay time, determine whether the maintenance men can complete a job or have to wait for the spare parts to arrive, this distribution directly affects the pattern of manning utilization.

As will be discussed in detail in the experimental design section, this maintenance model is substituted into Holck and Ticknor's simulation, and manning is tested for its effect on the overall airlift system. If the supply distribution is also changed, the effect of different manning levels would be confounded with the effect of a different supply distribution. Conversely, if the supply distribution is not changed, any difference in the significance of manning would be directly attributable to the manning model. Therefore, this model will use the same distribution of supply times as Holck and Ticknor used.

Summary

This chapter identified the elements of the conceptual model that required quantification, so that a mathematical model of the maintenance system could be developed. The requirement to model at the subsystem and discrete AFSC levels prevented the use of previously derived distributions of numbers of discrepancies and repair times. Shaw's equations are used to determine the discrepancies encountered, based on sortie length. Repair times are drawn from distributions that are estimated for each subsystem. Every subsystem, on each aircraft, could be modeled in this manner, but only the ten most critical subsystems, on the C-141 and C-5, are included in this model. This tailors the model to a wartime scenario and keeps the model small enough for ease of computerization, without sacrificing the detail required for investigation of the inner processes in the maintenance function. The maintenance force was separated into effective maintenance teams available, by AFSC, and the probabilities of using each AFSC were estimated by analysis of historical data. Finally, the supply requirements are modeled exactly as previously derived in Holck and Ticknor's simulation. With a mathematical representation of these elements, the model is ready to be computerized, and that process is the subject of the next chapter.

V Computerization

Introduction

Since mathematical notation is the basic language of the computer, translating the mathematical model of the previous section into a computer-consumable product is the next logical step in the simulation process (Ref 20:302). The particular computer language, selected for this translation process, determines the ease with which the translation is made and how well the structure and logic of the system can be represented in the computer program. This chapter details selection of the computer language, the general approach taken in developing the model, the specific form of the model, and verification of the model. As a whole, this chapter is a description of the tool, in the form of a computer model, used to analyze the maintenance system.

Language

A special purpose simulation language has the advantage of incorporating the common functions associated with describing a system. Creation of random numbers and variates, mechanisms for time advancement, formatted data output, and debugging mechanisms are only a few of the features built into a special purpose language for ease of programming (Ref 20:107). SLAM, Simulation Language for Alternative Modeling, (Ref 16) was chosen to model the maintenance system because of its flexibility and the usefulness of its built-in functions.

The network portion of SLAM easily models the queuing situation found in the allocation of maintenance resources to aircraft. Additionally, the symbolic representations of the SLAM network (Ref 16:130) provide a visual representation of the logic of the flow through the maintenance system. Reliable random number generators support the requirement for conditional branching, and verified random variate generators can provide the repair times. SLAM's clock mechanism can handle either the discrete event orientation or continuous flow. Very importantly, the built-in statistical analysis and output formats allow easy interpretation of the flow processses, one of the primary objectives of this study. Finally, the trace option is an invaluable tool in the verification and debugging processes (Ref 16).

SLAM Terminology

SLAM provides a framework, the network structure of nodes and branches, for modeling the flow of entities through a sequence of events, activities, and decisions (Ref 16). This section describes the individual network symbols used to describe the maintenance system in this thesis. The descriptions are brief and only meant to give the reader, who may be unfamiliar with SLAM, a general understanding of the network symbols and their functions.

Attribute. Attributes are values assigned to individual entities. These values are carried through the network to distinguish each individual entity. For example, the time that an entity entered the network can be carried as an attribute, often referred to as the mark time. Also, arbitrary numerical values can be assigned to designate an entity as a specific type. A C-141 might arbitrarily be designated by placing a vlue of one in an attribute, to distinguish it from a C-5 that would have a value of two in the same attribute.

Resource. Situations arise where an entity requires some item, servers or equipment, that must be carried through a portion of the network. These items are designated as resources and are put into the model in limited quantities.

Activity. Activities are the actual paths over which the entities move. They are the only place that explicit time delays occur, such as the time delay while maintenance is being accomplished. There does not have to be a time delay associated with an activity, but each activity must have a beginning and an ending node. Thus, the nodes represent a point of interest where an activity is starting or has just ended. Additionally, several activities can emanate from a single node, representing branching. One of three situations can be depicted with branching. First, all branches can be taken by duplicating the entity and routing one of the entities along each of the branches. Second, a probability can be assigned to each of the branches and the path of the entity will be determined probabilistically. Finally, conditions can be specified for each of the branches. Then, when an entity arrives, a duplicate of the entity will take each branch for which the condition is satisfied.

<u>GOON Node</u>. The GO ON or GOON node accomplishes no particular function, other than providing a break point between sequential activities. It is most often used as the point to begin branching, after some other activity.

<u>Assign Node</u>. The Assign node is used to assign values to the attributes of the entity passing through the node or to assign values to system variables. Attributes have already been discussed, and system variables are designated by XX(I), where I is an integer. The system variables are similar to any designated variable in FORTRAN, but they can be used in the network, a function, or a subroutine.

<u>Await Node</u>. Await nodes are used to assign resources to the entities that pass through the node. If resources are available, they are assigned to the entity and it continues through the network. If all resources are being used, the entity waits at the node until resources become available. Then, the resources are assigned and the entity continues through the network.

<u>Free Node</u>. The free node is used to take resources from an entity and make them available for assignment to the next entity at an await node.

Queue Node. Queue nodes represent the waiting lines for service. Normally, an entity will enter a queue node and wait there until some server, in a following activity, is available. However, in this model, the queues are used as simple waiting lines, controlled by a match node. There are no service activities following the queues.

Match Node. The match node controls several queues. It follows the queues, in the network, and searches the entities waiting in the queues for particular values of a designated attribute. When every queue that is controlled by the match node has an entity with that particular value in its designated attribute, all of those entities are allowed to proceed in the network.

Accumulate Node. The accumulate node releases one entity to proceed in the network, when a prescribed number of entities have arrived to it. It is used in this thesis to combine the subsystems of an aircraft, when they are matched by the match node, into a single aircraft.

Event Node. The event node allows the modeler to design a function not specifically included in any of the other SLAM nodes. The arrival of an entity at an event node causes subroutine EVENT to be called. This is a FORTRAN subroutine that supplements the SLAM network by allowing the modeler to include extensive mathematical equations or perform some logic not provided by any other node. The attributes of the entity can be changed in the subroutine, and when the subroutine has run, the entity continues in the network.

Function USERF. The USERF function is a user-defined FORTRAN function. It can be called from the network or a subroutine, and it returns a single value stored in the memory location called USERF.

These descriptions are not complete and do not represent all of the capabilities of the SLAM network, but they should suffice to acquaint a casual reader with the terminology used in the description of the model. The full capabilities of the SLAM language were not exercised in this model, so only the appropriate parts were discussed. For a more detailed explanation, the reader is referred to Introduction to Simulation and Slam (Ref 16).

General Approach

The flexibility of the SLAM language allows the system to be modeled as a network, within which, the event nodes are used to model the complex operations not provided by any other SLAM node (Ref 16:316). Thus, determination of numbers of discrepancies, using Shaw's equations, can take place within an event. As mentioned before, supply times are determined in a FORTRAN function, so any other distribution could easily be substituted. Both of these functions occur within an event node so an entity leaves that single node with all the information required in the maintenance network.

By determining all the requirements in an event, the rest of the network can directly model the logic of the flow through maintenance. As will be shown, the network presents a one-for-one matching of network portions with the logic steps developed in the conceptual model. This approach makes it easier to follow the logic in the model and should increase confidence in the fact that the computer model accurately reflects the conceptual model.

As a useful tool, this model of maintenance is designed to be incorporated into a larger simulation of strategic airlift, acting as an input-output system. Thus, the basic model begins at a single node in a network, where an aircraft arrives as the input to the maintenance model. The output is also a single node where the mission-ready aircraft will depart the maintenance system. However, for the development and initial testing of the model, an artificial input and output were designed.

Appendix A lists the SLAM statements and FORTRAN code that make up the actual computer model. Since the maintenance model is to be used in a larger simulation of the airlift system, some of the information required by the maintenance model would have normally been generated in other portions of the airlift system. A unique mark time in attribute 1, a numerical designator for type of aircraft in attribute 2, and the sortie lengths for the outbound and return sorties in attributes 3 and 4, respectively, are provided in the basic model, in lines 3650 to 3730. These four pieces of information are the only requirements for processing in the maintenance model. Additionally, an aircraft leaving maintenance would normally return to the airlift system, but, in the basic model, statistics are collected and the entity is terminated in lines 6210 to 6230.

Events

An aircraft enters the maintenance system at the node labeled G01, line 3740. The breakdown to ten separate subsystems (see Figure 10) is represented by routing entities along all ten branches, lines 3750 to 3840, to the event nodes. All ten of the events are identical, except for the parameters X1, X2, Y1, and Y2 (see Appendix A: lines 430-2360). Attribute 5 is set equal to the event number to identify each subsystem, the parameters are set, and the entity proceeds to line number 2420, where the computations begin. X1 and X2 are the "A" and "B" of Shaw's equations and are used in line 2420, with the outbound sortie length, to get the expected number of failures on that sortie. Then, the expected number of failures is used as the mean of a Poisson distribution, line 2470, to get the actual number of failures. This process is repeated for the return sortie in lines 2510 to 2560, to get the total number of failures in a subsystem.

If no failures occur, attribute 3, maintenance time, and attribute 4, supply time, are both set to zero (lines 2600-2630). If any failures occurred, a maintenance time

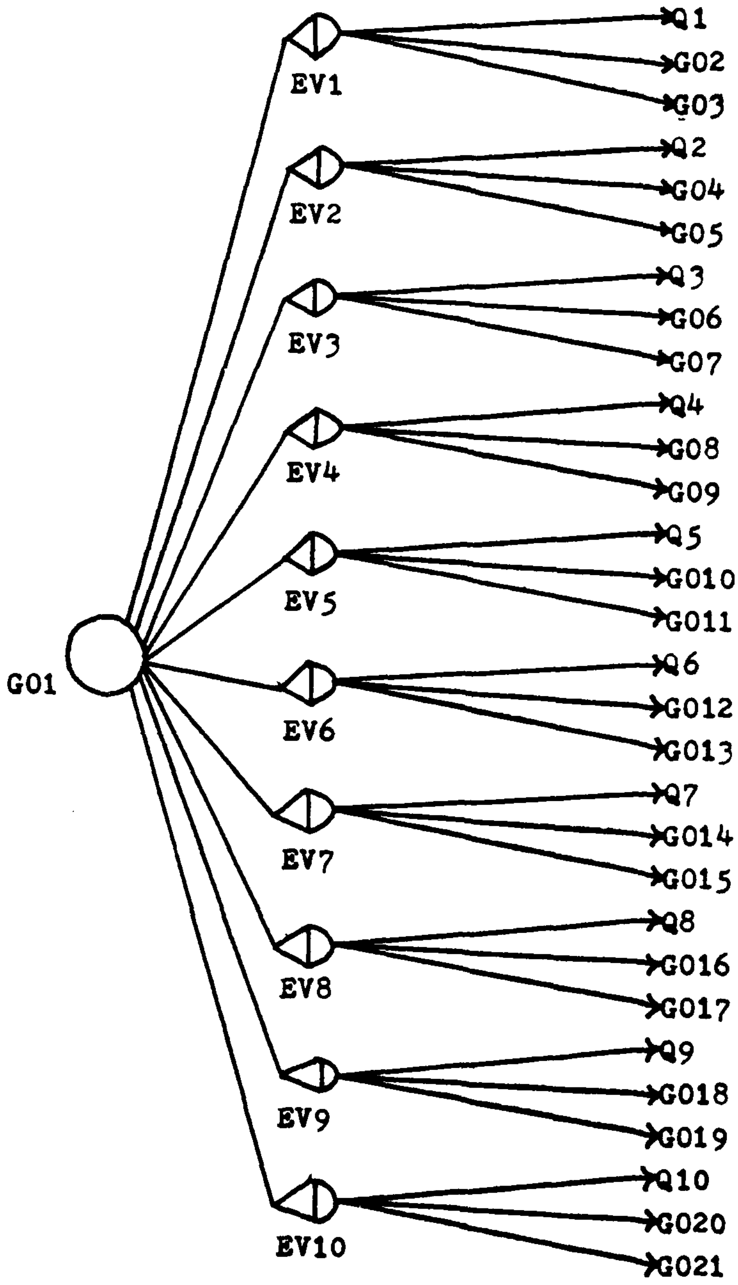

Fig 10. Entry Node, Events, and Initial Branching

is taken as a random variate from a gamma distribution with parameters Y1 and Y2, at line 2700. Lines 2740-2770 adjust that maintenance time for multiple failures. Only one maintenance team will be assigned to each subsystem, so more time will be taken as the number of failed parts increase. There is no data available for the effect of this assumption, so the time increase factors are arbitrary. They represent the assumption that troubleshooting and actual repair time will increase, as the number of failed parts increase. After four components, any more will require negligible time, since a large portion of the subsystem would be dismantled to replace four components.

If any components failed, a call is made to the supply user function, and the supply delay is returned at line 2810. This delay time represents the off-base supply action. Since parts would have to be ordered and delivered, not all of the maintenance time can be accomplished at once. Thus, if there is a supply delay, the maintenance time is divided in half, line 2870. When the subsystem returns to the network portion of the model, it will be assigned personnel and go through a maintenance activity two separate times. The first time through, half of the original maintenance time will be spent simulating the troubleshooting and removal of the bad part. Then the supply delay occurs, and the second time through maintenance represents the last half of the original maintenance time, to replace and test the part.

Supply Function

The supply function, as discussed previously, is derived from historical data. It consists of a separate, tabular distribution for each aircraft, lines 3100-3450. However, lines 3050 and 3060 are included as control statements. On line 3050, only a fixed percentage of candidates are given a supply delay. This percentage is set, in the model, at 25 percent, and it represents the analyst's best estimate of the Not Mission Capable due to Supply (NMSC) rate. The other control feature, line 3060, allows the analyst to set a time, before which supply will not be a factor. This represents the use of war reserve material, stockpiled on the base, and the analyst must estimate how long those supplies will last. Regardless, the end result is that the supply delay, zero or greater, is returned to the event that called the user function.

Network

Once the entity completes an event, the subsystem has its maintenance time set in attribute 3 and its supply time in attribute 4. The portion of the network, between event node and a queue, makes the logic decisions of the conceptual model. As each subsystem departs its event, it follows one of three paths. If there were no discrepancies, maintenance time is zero, and the subsystem proceeds directly to its appropriate queue to wait for completion of maintenance on all ten subsystems. Otherwise, if the aircraft is a C-141, it goes to the first GOON node listed; and if it is a C-5, it goes to the second GOON node (see Figure 10).

At these GOON nodes, all of the subsystems follow the same pattern of logic, so only the first subsystem, that went through Event 1, will be shown. Lines 3860-3880 of Appendix A show the conditional branching to the GOON nodes or the queue. An expanded view of this process, for Event 1, is shown in Figure 11. At G02, a probabilistic decision determines the AFSC required to fix the discrepancy on a C-141. The probabilities come form Table IV in Chapter IV, and AW1 and AW4 represent the await nodes where the AFSCs are allocated to the subsystems. The branch going to G022 represents the case when an AFSC that has not been modeled is required. Since an infinite resource of those AFSCs is assumed, the await nodes are bypassed and maintenance takes place on the way to G022. The code for these decisions is on lines 3890-3920. Likewise, the decisions for a C-5 are represented on lines 3930-3970.

Since all of the maintenance resource sub-networks are exactly the same, except for the particular AFSC being used, only the sub-network using 431R2 AFSC will be explained. This portion of the network is shown in Figure 12, and it corresponds to lines 5170-5230 in Appendix A. When any one of the subsystems determines that it needs a flight controls specialist, the subsystem is sent to the await node, AW1. If there is a maintenance team available, maintenance begins

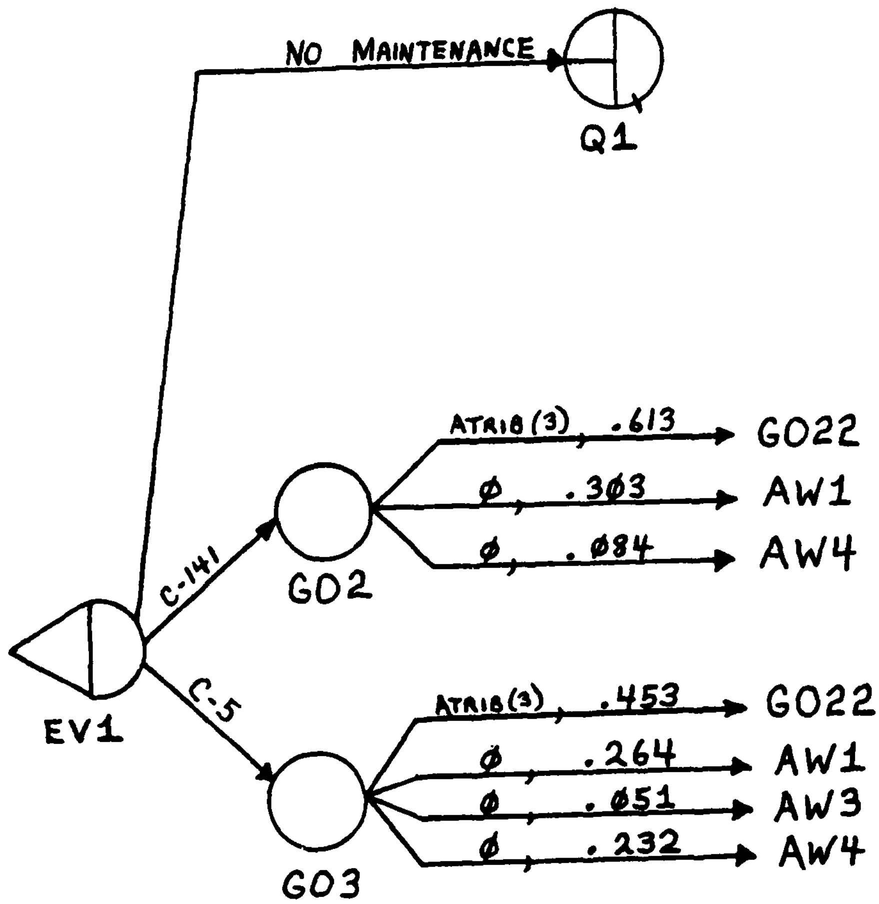

Fig 11. Expanded View of Initial Branching

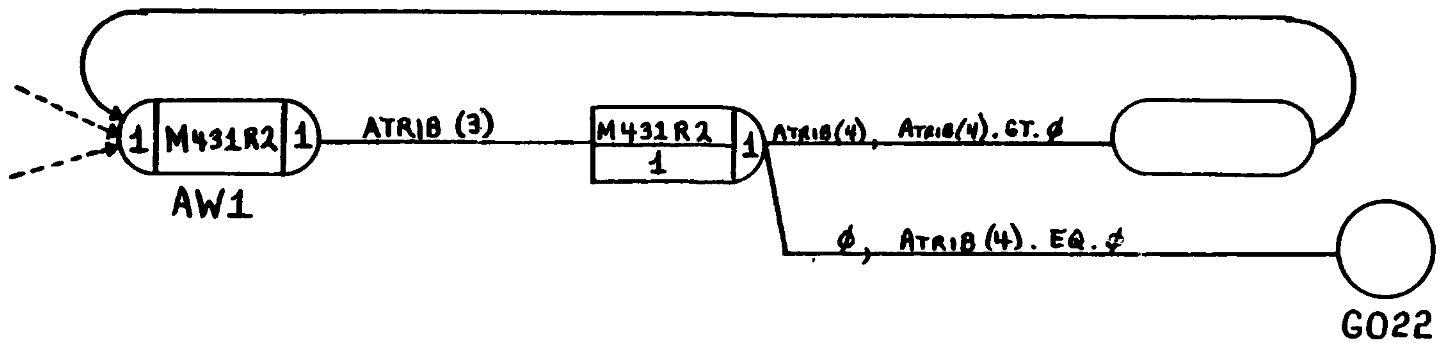

Fig 12. Resource Subnetwork

and proceeds for the time specified in attribute 3. Then, the team is freed, and if there was no supply delay, the subsystem goes to G022. If there was a supply delay, the maintenance is only half completed. The supply delay occurs, and supply time is set to zero at the assignment node, thus preventing the subsystem from continuing in an infinite loop. The subsystem goes back to have a maintenance team allocated again, goes through the second half of its maintenance, frees the personnel, and goes to G022.

All of the resource sub-networks follow the same pattern; so, unless a subsystem had no maintenance and went directly to its queue, all of them eventually get to G022. Figure 13 shows the possible paths to this point, for a subsystem going through Event 1. A subsystem, arriving at G022, could have come from one of the resource sub-networks or directly from an event, if no modeled resources were needed. If the subsystem came from a sub-network, any supply delay will have already been incurred, so the subsystem is routed directly to G023 (see Figure 14). If it came from an event and had a supply delay, that delay plus the second half of its maintenance are accounted for on the way to G023. This logic is listed in lines 5940-5970 of Appendix A.

Departing G023, only one branch is taken, with the conditional branching depending on the value in attribute 5. That value was set equal to the event number, so each subsystem arrives at its appropriate queue (lines 5980-6170).

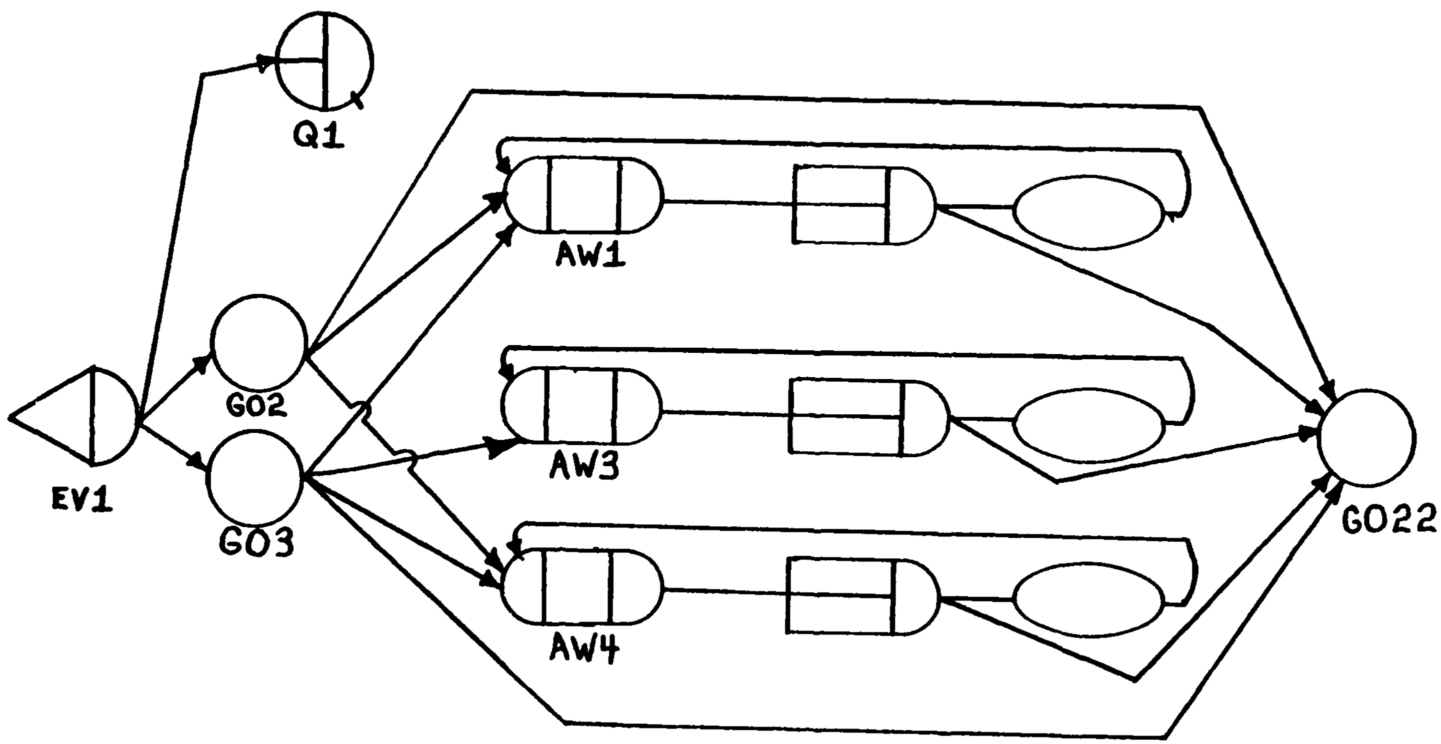

Fig 13. Possible Paths from Event 1

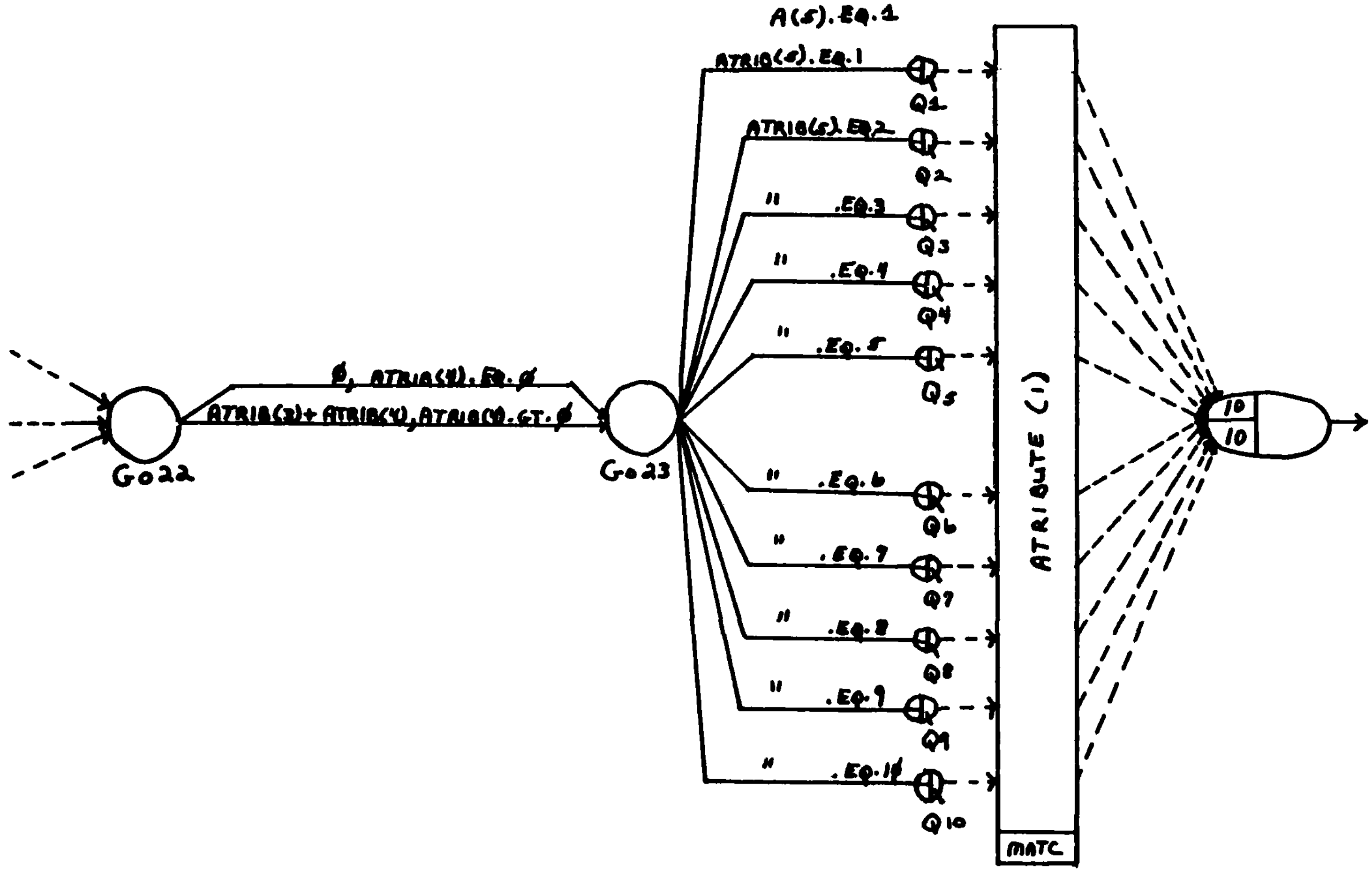

Fig 14. Reassembly of Subsystems

When all ten subsystems have completed maintenance, the match node matches the mark times of the ten subsystems and sends them to the accumulate node (line 6180). At line 6200, the ten subsystems are reassembled into a single entity, and the mission-ready aircraft departs the maintenance system.

Verification

The model, as represented in Appendix A, was verified through the use of the trace option in SLAM (Ref 16:156). The traces provide a detailed output of the step-by-step process of running the simulation. Every possible path through the network was followed, to ensure that the logic and execution were correct. The computer program does execute as the logic was intended. All conditional branching, matching, and accumulation work as planned. In addition, the validity of the probabilistic branching and random variate generators has been previously established for the SLAM program. Thus, this model is an accurate translation of the conceptual and mathematical models.

Summary

SLAM offers a simulation language that is almost perfectly suited to translate the mathematical model of Chapter IV into a computer model. The program, as translated, was presented with the coding in Appendix A and the symbols shown throughout this chapter. As demonstrated, the symbolic representation of the model duplicates the logic presented in

Chapter III, and the built-in functions of SLAM allow easy translation of the mathematical processes. The trace option allows thorough testing to ensure that the program functions as was intended. As a result, the computer model now represents a useful tool with which to continue this study of the maintenance system. The next chapter describes the manner in which this tool was applied to conduct this investigation.

VI Experimental Design

Introduction

The computer model is a tool and nothing more. Although the development of the computer model was the first objective of this thesis, the other three objectives are equally important. In order to test the implicit assumptions of the universal maintenance man concept and determine the significance of maintenance manning on the airlift system, the model is used in place of the actual system. By experimenting with the model and analyzing the results, some inferences about the actual system can be drawn. This chapter explains the design features incorporated into the computer model to aid in investigating the assumptions of the universal maintenance man concept, as well as the experiments designed to test those assumptions. Each of the last objectives of the thesis is discussed, in turn. The experiments for each objective are developed, and the results of the experiments are analyzed. Finally, the methods of variance reduction, incorporated into the model, are explained.

Proportionality

As Shannon suggests, the role of experimental design comes into play in both the planning and execution stages of model development (Ref 20:149). With a well planned idea of the experiments to be conducted, the model can be developed specifically to output appropriate statistics and to make the execution of the experimental design more efficient. Although this chapter follows the development of the computer model in this thesis, the experimental design was an important input in planning the development of the computer model.

One example of this prior planning is the ability to analyze the pattern of manpower utilization in maintenance. Since the universal maintenance man concept implicitly assumes that the manpower will be used in exact proportion to the established manning levels of the specialists, this assumption can be tested by direct reference to utilization statistics. By modeling each AFSC as a separate resource, controlled by an await node, SLAM provides statistics on the utilization of each AFSC and any delays due to the non-availability of any AFSC (Ref 16:159-161). Thus, on any run of the model, these statistics can be observed. If the implicit assumption is realistic, those statistics should show approximately equal utilization of each AFSC and no delays until nearly 100 percent of the maintenance force is being used.

SLAM outputs the actual number of resources used (Ref 16:161), and those numbers fluctuated from run to run. However, when converted to percentages of resource capacity, none of the runs ever approached an equal distribution of requirements. Table VI shows the percent utilization of each AFSC, as a representative sample of a run of the model. These are percentages of the number of teams available, for each

TABLE VI

Percent Utilization of AFSCs

AFSC	Average	Maximum
431R2	7%	28%
431W2	23%	100%
423X0	12%	49%
423X4	17%	75%
426X2	3%	13%
423X1	1%	9%
423X3	4%	32%
325X1	21%	89%
325X0	2%	24%
328X1	10%	49%
328X4	9%	75%

AFSC, and they show a wide disparity in useage. The average values vary from one percent to 23 percent, and the maximums vary from nine percent to 100 percent. These figures suggest that maintenance manpower is not used in exact proportion to the established manning levels of the specialists. Actually, the useage is very much disproportional.

<u>100 Percent Utilization</u>

As seen in Table VI, the initial runs of the model did not produce 100 percent utilization of the entire maintenance force. At the maximum, only one of the 11 AFSCs was fully utilized. Since the universal maintenance man concept requires all of the maintenance force to be busy before any delays occur, it is important to determine whether full utilization is feasible. The fact that 100 percent utilization did not occur in the initial runs of the model does not prove that it cannot occur. A slightly different pattern of aircraft arrivals might change the pattern of determining numbers of discrepancies and the associated AFSCs required to fix them, and 100 percent utilization could result.

In order to test the possibility of full utilization of the maintenance force, an experiment was designed to try to force maximum use of the maintenance force. The model was artificially set up to introduce a constant stream of aircraft, at very close time intervals, into the maintenance system. A total of 350 aircraft, more than the current total number of strategic airlift aircraft, were input to the model. As soon as the aircraft completed maintenance, they were routed back to the input node with a new set of input parameters. Three separate runs, with different seeds, were made in an attempt to saturate the maintenance model and force 100 percent utilization. Using different seeds, resulting in different random number streams, decreased the possibility that a non-representative outcome would be reported. However, the results were essentially the same for all three runs, and only one run will be presented here.

At the end of 120 hours of simulation time, the landing gear and instrument specialists were all working. The landing gear specialists, 431W2, had 66 subsystems waiting in their queue; and the instruments specialists, 325X1, had 179 subsystems in their queue. No other specialists were experiencing any backlog of jobs. The percentage utilization of each AFSC is presented in Table VII. Even at this unrealistically high demand rate, 100 percent utilization of the maintenance force is not achieved. The AFSCs in high demand tend to stop the flow of aircraft, before full utilization of the other AFSCs can be attained.

This result implies that 100 percent utilization of the maintenance force is not feasible, but it is still not conclusive proof. However, if full utilization cannot be attained under these unrealistic conditions, the possibility of it being attained under normal conditions is very small.

TABLE VII

Percent Utilization of AFSCs, Maximum Effort

AFSC	Average	Maximum
431R2	35%	82%
431W2	99%	100%
423X0	40%	100%
423X4	91%	100%
426X2	14%	37%
423X1	4%	11%
423X3	16%	43%
325X1	99%	100%
325X0	12%	41%
328X1	53%	100%
328X4	55%	100%

Thus, any simulation that requires 100 percent utilization before any delays occur, such as the case when universal maintenance men are used, would not correctly reflect the maintenance system.

Significance of Maintenance Manning

The last objective of this thesis is to determine the significance of maintenance manning on the airlift system. Since the implicit assumptions of the universal maintenance man concept do not realistically represent the actual maintenance system, the effects of maintenance manning may have been incorrectly assessed in previous simulations that used universal maintenance men. With the maintenance model, developed in this thesis, included in a simulation of the airlift system, a more accurate assessment of the effects of maintenance manning can be made. This section details the selection of an appropriate simulation of the airlift system within which the effects of the maintenance model could be tested, and the experimental design and results of that test are discussed.

The best and most meaningful experimentation would come from including this model in a large simulation, like M-14, that represented a network of bases. This would allow the maintenance force to be dispersed and the ripple effects, through the bases, could be analyzed. However, M-14 is not yet developed and debugged to the point where anything but unlimited maintenance resources have been used. Thus, it is not possible to conduct a large-scale experiment with multiple bases. However, Holck and Ticknor developed a simulation of airlift capability (Ref 8), and their doubts about the validity of the maintenance portion of their model partially prompted this investigation of the universal maintenance man concept.

In their simulation, Holck and Ticknor modeled the resupply of Europe, using aggregate bases in the United States and Europe. In early runs of their model, only 65 percent of the maintenance force was ever used at one time, and since they used universal maintenance men, no delays were ever seen. Thus, manning had no effect on their measure of airlift capability, total tons delivered in 30 days. Using a 2^{k-p} fractional design, they determined that time to zero War Reserve Material (WRM) and the number of aircraft available were the only statistically significant factors in their model. Additionally, resupply time appeared to have some influence (Ref 8:74).

Since Holck and Ticknor did use universal maintenance men, did not find maintenance manning significant, and did not think that the results of the maintenance portion of their model were realistic, their simulation was chosen to test the maintenance model developed in this thesis. By substituting this maintenance model for the maintenance portion of their model, without changing any other part of their model, any difference in the outputs would be directly attributable to the more detailed modeling of maintenance manning. As previously mentioned, the distribution of resupply times, used in this thesis model, was taken directly from Holck and Ticknor's simulation. Thus, any changes in outputs would not be due to a different resupply distribution. Again, this was done to isolate only the effects of maintenance manning.

Holck and Ticknor's simulation, with the maintenance model developed in this thesis substituted for their maintenance portion, is listed in Appendix B. In a simulation of the entire airlift system, there are many factors that might have a significant effect on the capability of the airlift fleet to deliver cargo. However, Holck and Ticknor determined that, in their model, only three factors were significant. This study is particularly concerned with the effect of a fourth factor, maintenance manning. Thus, only four factors were tested in the experimental design. Each factor, number of aircraft, time to zero WRM, resupply time, and maintenance manning levels, was initially set at the level expected for the scenario. Then, each factor was changed to a second experimental level to determine the effect of such changes.

Again, to keep the conditions of this experiment as close as possible to Holck and Ticknor's original experiment, their initial and experimental levels were used for number of aircraft, time to zero WRM, and resupply time. Initially, 176 C-141s were used, and the experimental level was changed to 229, representing the increased capacity of the stretched C-141B. The initial resupply times, reflected in lines 5550 to 5970 of Appendix B, were experimentally reduced by 23 percent to represent the expected slowdown in supply channels during wartime. Finally, the time to deplete the stock of WRM was initially determined to be 12 days. The experimental level was set at 24 days, reflecting a buildup of prepositioned supplies (Ref 8).

Since manning is the only factor not previously tested, the levels used will be explained. The initial level is the structure as derived in Chapter IV (see Table V). This structure represents the maximum number of effective maintenance teams currently available. For testing purposes, the alternate level was established as 90 percent of the initial teams available. This ten percent reduction is realistic, because not all of the strategic airlift aircraft are used in Holck and Ticknor's simulation. Some aircraft are dedicated to previously committed missions, and a portion of the maintenance men would be used to support those missions. Also, the number of effective teams available is directly related to current manning levels, which fluctuate with recruiting effectiveness.

In order to determine the effects and interactions of these changes, a 2^4 full factorial design (Ref 16:164) was required. Each distinct combination of initial and changed levels of the four factors was run twice, with different random number streams, so a total of 32 runs of the simulation were made. The data from these runs was analyzed by a four-way ANOVA using SPSS (Ref 14:410). Holck and Ticknor had demonstrated that three-way and higher interactions were negligible, so only the main and two-way interactions were analyzed.

Table VIII shows the results of the experimental runs of the simulation. Under the factors, a "-" represents the initial level of the factor, and a "+" represents the experimental level. The sixteen runs represent the 2^4 full factorial design, and each combination of levels gave two observations, the normal and antithetic runs. The first observation used a normal random number stream, and the antithetic run used a stream that consisted of the complements of the normal random numbers (1 - normal random number) (Ref 16:150). The effect of this antithetic sampling will be discussed later in this chapter under variance reduction. The measure of effectiveness, in the model, was thousands of tons of cargo delivered, and the outcomes are listed for each run.

These results were input to SPSS and the four-way ANOVA was run. Table IX shows the results of that ANOVA. As can be seen by the very small F-value, changing the manning level had very little effect on the output of the airlift system. This is not a result of not having delays due to manning. Delays were shown on all of the runs using

TABLE VIII

Results of Experimental Runs

FACTORS

Run	War Reserve Material	Aircraft	Supply	Maint	Normal Seed	Anti Seed
1	-	-	-	-	126.8	132.2
2	-	+	-	-	150.9	152.1
3	-	+	+	-	158.5	161.7
4	-	+	+	+	158.2	159.5
5	+	+	+	+	183.3	185.7
6	-	-	-	+	126.9	132.2
7	-	-	+	+	134.7	137.2
8	+	-	+	+	158.7	160.7
9	-	-	+	-	134.3	137.2
10	+	-	+	-	156.9	160.7
11	+	+	+	-	183.9	186.9
12	-	+	-	+	148.7	153.7
13	+	+	-	+	182.0	185.6
14	+	-	-	-	156.7	160.0
15	+	+	-	-	183.2	186.5
16	+	-	-	+	157.1	160.0

TABLE IX

ANOVA Results

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	10969.061	4	2742.265	598.754	.001
WRM	6135.550	1	6135.550	1339.653	.001
C-141	4706.925	1	4706.925	1027.723	.001
Resupply	126.000	1	126.000	27.513	.001
Maint	.578	1	.578	.126	.726
2-Way Interactions	107.869	6	17.978	3.925	.009
WRM C-141	18.758	1	18.758	4.096	.056
WRM Resupply	84.825	1	84.825	10.521	.001
WRM Maint	.025	1	.025	.006	.941
C-141 Resupply	1.320	1	1.320	.288	.597
C-141 Maint	2.940	1	2.940	.642	.432
Resupply Maint	.000	1	.000	.000	.993
Explained	11076.931	10	1107.693	241.857	.001
Residual	96.179	21	4.580		
Total	11173.110	31	360.423		

regular seeds, and nine of the antithetic runs also showed some delays. Apparently, in this model, these delays do not cause enough disruption of the system to significantly affect the outcome.

Variance Reduction

The simulation model, as listed in Appendix B, uses the built-in features for variance reduction in SLAM. The paired smaples for the experimental design were obtained using antithetic sampling, as SLAM suggests (Ref 16:485). The first observation was obtained using normal seeds for the random number generators. The second observation, however, used the antithetic seeds, including a negative correlation between the observations. This process is initiated by specifying a negative initial seed value in SLAM, and it seems to be an effective method of variance reduction (Ref 16:485).

Both Holck and Ticknor's model and the maintenance model can incorporate another feature for variance reduction, correlated sampling. Each of the random number streams, provided by SLAM, is used exclusively for one purpose. In other words, every call to a random variate generator or a random number generator uses a different stream. By specifying the same seeds for different runs, the same series of events can be introduced to both runs. However, the use of both antithetic sampling and common streams can increase the variance, so extreme care must be used if both techniques are utilized (Ref 16:487).

Summary

The experimental design used in this thesis was considered early in the development of the maintenance model to structure the output statistics and the inputs to the model. Using the model as a tool, specific tests were developed to satisfy each of the objectives of this study. Both the basic model, Appendix A, and Holck and Ticknor's simulation with this maintenance model included, Appendix B, were used in those tests. The results of those tests do not support the implicit assumptions of the universal maintenance man concept; and in a simulation that uses aggregated bases, maintenance manning levels do not appear to be statistically significant to airlift capability. The conclusions and recommendations, resulting from these findings, will be presented in the next chapter.

VII Conclusions and Recommendations

The primary goal of this thesis was the investigation of the implicit assumptions of the universal maintenance man concept. In order to conduct this investigation, a great deal of effort was expended in developing a more detailed model of the maintenance system so the internal processes could be analyzed. The model is not a complete and universally acceptable representation of the maintenance system, but it is offered as an approach to modeling and a general guide to methodology. The model does suffice as a tool for investigation of the nature of the internal processes in maintenance, and those processes are the basis of the implicit assumptions of the universal maintenance man concept.

Conclusions

The results of this study are clear enough to draw several conclusions. First, the maintenance system does not operate in a manner that supports the implicit assumptions of the universal maintenance man concept. Discrepancies do not occur in proportion to the numbers of maintenance specialists capable of repairing them. Also, 100 percent utilization of the maintenance force does not appear to be feasible.

If maintenance manning is to be modeled, in a simulation that requires details of the maintenance process, the approach used in this thesis will provide sufficient details of manning utilization and possible delays. However, it is not clear that maintenance manning must be modeled at all. In Holck and Ticknor's simulation, maintenance did not have any significant effect. This suggests that it may be possible to delete maintenance manning from a model of strategic airlift.

Recommendations

The approach to modeling the maintenance portion of a strategic airlift simulation, developed in this thesis, is a viable alternative to the use of universal maintenance men. It is not as large and compelx as the Logistics Composite Model, but it will provide some level of detail concerning the maintenance function. If a simulation of strategic airlift requires detailed maintenance statistics, this approach is suggested.

Finally, each simulation effort should determine the likely effects of delays due to maintenance manning. If those effects will not be significant, for the purpose of that particular model, maintenance manning may not have to be modeled. If manning is not modeled, it may be possible to represent the total time in maintenance by one distribution of maintenance times.

Further Research

The effects of this maintenance model, in a simulation that uses a network of bases, has not been determined. The fact that the maintenance force will be unevenly distributed among many bases could change the significance of manning. The next logical step, in this area of research, would be to develop a network model of the MAC bases and try to incorporate this model into the network.

Also, the maintenance data tapes, as discussed earlier, are extremely difficult to use. If a program could be developed that would accomplish the basic functions of the CDEP and have variable output formats and contents, it would be a great aid for future researchers.

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Appendix A

Basic Maintenance Model

```
WPS,CM265000,T150,IO100.  T810372,STANBERRY,BOX4577
ATTACH,PROCFIL,SLAMPROC,ID=AFIT.
FTN5,ANSI=0.
BEGIN,SLAM,,M=LGO,PL=10000.
C
C
C
C
C
      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7)
      DIMENSION NSET (45000)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET (45000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=45000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END
```

```
      SUBROUTINE EVENT (I)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      GO TO (1,2,3,4,5,6,7,8,9,10),I
C
C  EVENT 1        SETS PARAMETERS FOR W.U.C. #11.
C
C  ** FOR A C-141 **
C
 1    ATRIB(5)=1
      IF(ATRIB(2).EQ.2) GO TO 11
      X1=.0336
      X2=.0604
      Y1=.9954
      Y2=3.0421
      GO TO 100
C
C  ** FOR A C-5 **
C
 11   X1=.373
      X2=.012
      Y1=3.0737
      Y2=.9044
      GO TO 100
C
C  EVENT 2        SETS PARAMETERS FOR W.U.C. # 13.
C
C  ** FOR A C-141 **
C
 2    ATRIB(5)=2
      IF (ATRIB(2).EQ.2) GO TO 12
      X1=.0317
      X2=.0500
      Y1=.9015
      Y2=1.9368
      GO TO 100
C
C  ** FOR A C-5 **
C
 12   X1=.614
      X2=.035
      Y1=1.2269
      Y2=1.4690
      GO TO 100
C
C  EVENT 3        SETS PARAMETERS FOR W.U.C. # 14.
C
C  ** FOR A C-141 **
C
 3    ATRIB(5)=3
```

AD-A115 745   AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOO--ETC F/G 1/2
AN IMPROVED MAINTENANCE MODEL FOR THE SIMULATION OF STRATEGIC A--ETC(U)
MAR 82 W P STANBERRY

UNCLASSIFIED AFIT/GST/OS/82M-13   NL

2 of 2

END
DATE
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DTIC

```
      IF (ATRIB(2).EQ.2) GO TO 13
      X1=.0129
      X2=.0278
      Y1=1.3925
      Y2=2.1242
      GO TO 100
C
C  ** FOR A C-5 **
C
 13   X1=.074
      X2=.018
      Y1=1.7996
      Y2=1.5665
      GO TO 100
C
C  EVENT 4        SETS PARAMETERS FOR W.U.C. # 23.
C
C  ** FOR A C-141 **
C
 4    ATRIB(5)=4
      IF (ATRIB(2).EQ.2) GO TO 14
      X1=.0524
      X2=.0772
      Y1=.7625
      Y2=3.0044
      GO TO 100
C
C  ** FOR A C-5 **
C
 14   X1=.253
      X2=.096
      Y1=1.1153
      Y2=1.6712
      GO TO 100
C
C  EVENT 5        SETS PARAMETERS FOR W.U.C. # 42.
C
C  ** FOR A C-141 **
C
 5    ATRIB(5)=5
      IF (ATRIB(2).EQ.2) GO TO 15
      X1=.0065
      X2=.0070
      Y1=1.1171
      Y2=1.2157
      GO TO 100
C
C  ** FOR A C-5 **
C
 15   X1=.118
```

```
      X2=.030
      Y1=.6374
      Y2=2.6955
      GO TO 100
C
C  EVENT 6        SETS PARAMETERS FOR W.U.C. # 45.
C
C  ** FOR A C-141 **
C
 6    ATRIB(5)=6
      IF (ATRIB(2).EQ.2) GO TO 16
      X1=.0097
      X2=.0292
      Y1=.4326
      Y2=4.3023
      GO TO 100
C
C  ** FOR A C-5 **
C
 16   X1=.151
      X2=.048
      Y1=.5574
      Y2=3.6602
      GO TO 100
C
C  EVENT 7        SETS PARAMETERS FOR W.U.C. # 46.
C
C  ** FOR A C-141 **
C
 7    ATRIB(5)=7
      IF (ATRIB(2).EQ.2) GO TO 17
      X1=.012
      X2=.008
      Y1=1.376
      Y2=2.0044
      GO TO 100
C
C  ** FOR A C-5 **
C
 17   X1=.111
      X2=.012
      Y1=.5229
      Y2=3.5153
      GO TO 100
C
C  EVENT 8        SETS PARAMETERS FOR W.U.C. # 51.
C
C  ** FOR A C-141 **
C
 8    ATRIB(5)=8
```

```
      IF (ATRIB(2).EQ.2) GO TO 18
      X1=.0218
      X2=.0181
      Y1=.1208
      Y2=9.931
      GO TO 100
C
C  ** FOR A C-5 **
C
 18   X1=.122
      X2=.049
      Y1=.1225
      Y2=13.9255
      GO TO 100
C
C  EVENT 9        SETS PARAMETERS FOR W.U.C. # 72.
C
C  ** FOR A C-141 **
C
 9    ATRIB(5)=9
      IF (ATRIB(2).EQ.2) GO TO 19
      X1=.0709
      X2=.0266
      Y1=.0439
      Y2=29.5124
      GO TO 100
C
C  ** FOR A C-5 **
C
 19   X1=.262
      X2=.085
      Y1=.3622
      Y2=4.8696
      GO TO 100
C
C EVENT 10        SETS PARAMETERS FOR W.U.C. 55 & 73.
C
C  ** FOR A C-141 **
C
 10   ATRIB(5)=10
      IF (ATRIB(2).EQ.2) GO TO 20
      X1=.0138
      X2=.0120
      Y1=.1114
      Y2=12.5641
      GO TO 100
C
C  ** FOR A C-5 **
C
 20   X1=.138
```

```
      X2=.063
      Y1=.2707
      Y2=7.2738
C
C  ADDRESS 100       FIRST, DETERMINES EXPECTED NUMBER OF FAILURES
C  FOR THE APPROPRIATE WORK UNIT CODE (USING THE PARAMETERS,
C  X1 & X2, SET ABOVE), FOR THE OUTBOUND SORTIE.
C
 100  XX(2) = X1 + X2 * ATRIB(3)
C
C  USE EXPECTED NUMBER OF FAILURES AS THE MEAN OF A POISSON
C  DISTRIBUTION TO GET THE NUMBER OF FAILURES GENERATED.
C
      X = NPSSN(XX(2),2)
C
C DETERMINE EXPECTED NUMBER OF FAILURES FOR RETURN SORTIE.
C
      XX(2) = X1 + X2 * ATRIB(4)
C
C  DETERMINE NUMBER OF FAILURES ON RETURN SORTIE AND, ADD
C  TO THE NUMBER OF FAILURES ON THE OUTBOUND SORTIE.
C
      X = X + NPSSN(XX(2),2)
C
C  IF NO FAILURES OCCUR, BOTH MX AND SUPPLY TIMES ARE ZERO.
C
      IF(X.EQ.0) THEN
        ATRIB(3)=0
        ATRIB(4)=0
      RETURN
      ENDIF
C
C  IF FAILURES OCCURRED, DETERMINE TIME TO REPAIR (USING
C  PARAMETERS, Y1 & Y2, SET PREVIOUSLY).  ALL TIMES COME
C  FROM GAMMA DISTRIBUTIONS.
C
      IF(X.GT.0) Y=GAMA(Y1,Y2,3)
C
C  ADJUST MX TIME IF MORE THAN ONE PART FAILED IN THIS SUBSYSTEM.
C
      IF (X.EQ.1) ATRIB(3)=Y
      IF (X.EQ.2) ATRIB(3)=1.5*Y
      IF (X.EQ.3) ATRIB(3)=1.75*Y
      IF (X.GE.4) ATRIB(3)=2.0*Y
C
C DETERMINE SUPPLY DELAY, IF ANY, IN USERF.
C
      ATRIB(4) = USERF(1)
C
C  IF THERE WILL BE A SUPPLY DELAY, DIVIDE MX TIME IN HALF,
```

```
C  SINCE SOME WORK WILL BE DONE BEFORE AND SOME AFTER THE
C  SUPPLY DELAY.
C
      IF (ATRIB(4).GT.0) ATRIB(3)=ATRIB(3)/2
      RETURN
      END
```

```
      FUNCTION USERF(I)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C
      GO TO (1),I
C*****************************************************
C  THIS FUNCTION IS USED TO DETERMINE HOW LONG AN ACFT  **
C  IS DOWN WHILE WAITING FOR SUPPLY.  NOTE THAT SUPPLY  **
C  IS NOT A FACTOR FOR THE FIRST 12 DAYS (288 HOURS)    **
C  THIS IS DUE TO LOCAL STOCK AND WRSK STOCKPILES.      **
C*****************************************************
C
C** FIRST, DETERMINE IF SUPPLY IS A FACTOR **
C
 1    IF (DRAND(3).LE..75) GO TO 300
      IF (TNOW.LE.288) GO TO 300
C
C** FOR THE C141 **
C
      IF (ATRIB(2).EQ.2) GO TO 30
      X=DRAND(3)
      IF (X.LE..004) GO TO 301
      IF (X.LE..330) GO TO 302
      GO TO 303
 300  USERF=0
      RETURN
 301  USERF=(6000.*(X)+24.)+1.0
      RETURN
 302  USERF=(73.62*(X-.004)+48.)+1.0
      RETURN
 303  USERF=(143.28*(X-.330)+72.)+1.0
      RETURN
C
C** FOR THE C5 **
C
 30   X=DRAND(3)
      IF (X.LE..002) GO TO 304
      IF (X.LE..233) GO TO 305
      IF (X.LE..323) GO TO 306
      IF (X.LE..330) GO TO 307
      IF (X.LE..585) GO TO 308
      GO TO 309
 304  USERF=(12000.*(X)+24.)+1.0
      RETURN
 305  USERF=(103.9*(X-.002)+48.)+1.0
      RETURN
 306  USERF=(266.67*(X-.233)+72.)+1.0
      RETURN
 307  USERF=(1600.*(X-.323)+96.)+1.0
      RETURN
```

```
308 USERF=(97.17*(X-.338)+120.)*1.0
    RETURN
309 USERF=(57.83*(X-.585)+144.)*1.0
    RETURN
    END
```

```
;
; MAINTENANCE MODEL NETWORK
;
GEN,STANBERRY,MX MODEL,12/15/1981;
LIM,21,5,4000;
NETWORK;
     RES/M431R2(74),1;      FLT. CONTROLS MX PERS
     RES/M431W2(18),2;      LANDING GEAR MX PERS
     RES/M423X0(43),3;      ELECTRICAL SYSTEMS MX PERS
     RES/M423X4(57),4;      PNEUDRAULICS MX PERS
     RES/M426X2(193),5;     ENGINE MX PERS
     RES/M423X1(46),6;      ENVIRONMENTAL SYSTEMS MX PERS
     RES/M423X3(28),7;      FUEL SYSTEMS MX PERS
     RES/M325X1(45),8;      INSTRUMENTS MX PERS
     RES/M325X0(37),9;      AUTOPILOT MX PERS
     RES/M328X1(49),10;     NAVIGATION SYSTEMS MX PERS
     RES/M328X4(36),11;     INS & RADAR MX PERS
     CRE,.2,0.0,1,1000,1;
     ASS,XX(1)=XX(1)+1,
         ATRIB(3)=RNORM(7.7,.2),
         ATRIB(4)=RNORM(9.3,.2);
     ACT,,XX(1).LE.3,AS1;
     ACT,,XX(1).EQ.4;
     ASS,ATRIB(2)=2,XX(1)=0;
     ACT,,,G01;
 AS1 ASS,ATRIB(2)=1;
 G01 GOON,10;
     ACT,,,EV1;
     ACT,,,EV2;
     ACT,,,EV3;
     ACT,,,EV4;
     ACT,,,EV5;
     ACT,,,EV6;
     ACT,,,EV7;
     ACT,,,EV8;
     ACT,,,EV9;
     ACT,,,EV10;
 EV1 EVE,1,1;
     ACT,,ATRIB(3).EQ.0,Q1;
     ACT,,ATRIB(2).EQ.1,G02;
     ACT,,ATRIB(2).EQ.2,G03;
 G02 GOON,1;
     ACT,ATRIB(3),.613,G022;
     ACT,,.303,AM1;
     ACT,,.084,AM4;
 G03 GOON,1;
     ACT,ATRIB(3),.453,G022;
     ACT,,.264,AM1;
     ACT,,.051,AM3;
     ACT,,.232,AM4;
```

```
EV2   EVE,2,1;
      ACT,,ATRIB(3).EQ.0,Q2;
      ACT,,ATRIB(2).EQ.1,G04;
      ACT,,ATRIB(2).EQ.2,G05;
G04   GOON,1;
      ACT,ATRIB(3),.08,G022;
      ACT,,.473,AW2;
      ACT,,.145,AW3;
      ACT,,.302,AW4;
G05   GOON,1;
      ACT,ATRIB(3),.128,G022;
      ACT,,.047,AW1;
      ACT,,.472,AW2;
      ACT,,.078,AW3;
      ACT,,.201,AW4;
      ACT,,.074,AW8;
EV3   EVE,3,1;
      ACT,,ATRIB(3).EQ.0,Q3;
      ACT,,ATRIB(2).EQ.1,G06;
      ACT,,ATRIB(2).EQ.2,G07;
G06   GOON,1;
      ACT,ATRIB(3),.189,G022;
      ACT,,.254,AW1;
      ACT,,.105,AW3;
      ACT,,.228,AW4;
      ACT,,.156,AW8;
      ACT,,.068,AW9;
G07   GOON,1;
      ACT,ATRIB(3),.217,G022;
      ACT,,.163,AW1;
      ACT,,.127,AW3;
      ACT,,.493,AW4;
EV4   EVE,4,1;
      ACT,,ATRIB(3).EQ.0,Q4;
      ACT,,ATRIB(2).EQ.1,G08;
      ACT,,ATRIB(2).EQ.2,G09;
G08   GOON,1;
      ACT,ATRIB(3),.177,G022;
      ACT,,.434,AW5;
      ACT,,.389,AW8;
G09   GOON,1;
      ACT,ATRIB(3),.257,G022;
      ACT,,.413,AW5;
      ACT,,.330,AW8;
EV5   EVE,5,1;
      ACT,,ATRIB(3).EQ.0,Q5;
      ACT,,ATRIB(2).EQ.1,G010;
      ACT,,ATRIB(2).EQ.2,G011;
G010  GOON,1;
      ACT,ATRIB(3),.113,G022;
```

```
         ACT,,.078,AW1;
         ACT,,.707,AW3;
         ACT,,.051,AW5;
         ACT,,.051,AW9;
GO11     GOON,1;
         ACT,ATRIB(3),.235,GO22;
         ACT,,.576,AW3;
         ACT,,.189,AW5;
EV6      EVE,6,1;
         ACT,,ATRIB(3).EQ.0,Q6;
         ACT,,ATRIB(2).EQ.1,GO12;
         ACT,,ATRIB(2).EQ.2,GO13;
GO12     GOON,1;
         ACT,ATRIB(3),.023,GO22;
         ACT,,.912,AW4;
         ACT,,.065,AW8;
GO13     GOON,1;
         ACT,ATRIB(3),.082,GO22;
         ACT,,.720,AW4;
         ACT,,.146,AW6;
         ACT,,.052,AW8;
EV7      EVE,7,1;
         ACT,,ATRIB(3).EQ.0,Q7;
         ACT,,ATRIB(2).EQ.1,GO14;
         ACT,,ATRIB(2).EQ.2,GO15;
GO14     GOON,1;
         ACT,ATRIB(3),.068,GO22;
         ACT,,.540,AW7;
         ACT,,.392,AW8;
GO15     GOON,1;
         ACT,ATRIB(3),.097,GO22;
         ACT,,.416,AW3;
         ACT,,.209,AW7;
         ACT,,.278,AW8;
EV8      EVE,8,1;
         ACT,,ATRIB(3).EQ.0,Q8;
         ACT,,ATRIB(2).EQ.1,GO16;
         ACT,,ATRIB(2).EQ.2,GO17;
GO16     GOON,1;
         ACT,ATRIB(3),.000,GO22;
         ACT,,.992,AW8;
GO17     GOON,1;
         ACT,ATRIB(3),.077,GO22;
         ACT,,.528,AW8;
         ACT,,.277,AW9;
         ACT,,.118,AW10;
EV9      EVE,9,1;
         ACT,,ATRIB(3).EQ.0,Q9;
         ACT,,ATRIB(2).EQ.1,GO18;
         ACT,,ATRIB(2).EQ.2,GO19;
```

```
G018  GOON,1;
      ACT,ATRIB(3),.008,G022;
      ACT,,.992,AW10;
G019  GOON,1;
      ACT,ATRIB(3),.012,G022;
      ACT,,.588,AW10;
      ACT,,.400,AW11;
EV10  EVE,10,1;
      ACT,,ATRIB(3).EQ.0,Q10;
      ACT,,ATRIB(2).EQ.1,G020;
      ACT,,ATRIB(2).EQ.2,G021;
G020  GOON,1;
      ACT,ATRIB(3),.002,G022;
      ACT,,.567,AW10;
      ACT,,.431,AW11;
G021  GOON,1;
      ACT,ATRIB(3),.042,G022;
      ACT,,.086,AW5;
      ACT,,.872,AW11;
AW1   AWA(1),M431R2/1,1;
      ACT,ATRIB(3);
      FRE,M431R2/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW1;
AW2   AWA(2),M431W2/1,1;
      ACT,ATRIB(3);
      FRE,M431W2/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW2;
AW3   AWA(3),M423X0/1,1;
      ACT,ATRIB(3);
      FRE,M423X0/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW3;
AW4   AWA(4),M423X4/1,1;
      ACT,ATRIB(3);
      FRE,M423X4/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW4;
AW5   AWA(5),M426X2/1,1;
      ACT,ATRIB(3);
      FRE,M426X2/1,1;
```

```
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW5;
AW6   AWA(6),M423X1/1,1;
      ACT,ATRIB(3);
      FRE,M423X1/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW6;
AW7   AWA(7),M423X3/1,1;
      ACT,ATRIB(3);
      FRE,M423X3/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW7;
AW8   AWA(8),M325X1/1,1;
      ACT,ATRIB(3);
      FRE,M325X1/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW8;
AW9   AWA(9),M325X0/1,1;
      ACT,ATRIB(3);
      FRE,M325X0/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW9;
AW10  AWA(10),M328X1/1,1;
      ACT,ATRIB(3);
      FRE,M328X1/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW10;
AW11  AWA(11),M328X4/1,1;
      ACT,ATRIB(3);
      FRE,M328X4/1,1;
      ACT,,ATRIB(4).EQ.0,G022;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW11;
G022  GOON,1;
      ACT,ATRIB(3)+ATRIB(4),ATRIB(4).GT.0,G023;
      ACT,,ATRIB(4).EQ.0,G023;
G023  GOON,1;
```

```
        ACT,,ATRIB(5).EQ.1,Q1;
        ACT,,ATRIB(5).EQ.2,Q2;
        ACT,,ATRIB(5).EQ.3,Q3;
        ACT,,ATRIB(5).EQ.4,Q4;
        ACT,,ATRIB(5).EQ.5,Q5;
        ACT,,ATRIB(5).EQ.6,Q6;
        ACT,,ATRIB(5).EQ.7,Q7;
        ACT,,ATRIB(5).EQ.8,Q8;
        ACT,,ATRIB(5).EQ.9,Q9;
        ACT,,ATRIB(5).EQ.10,Q10;
Q1      QUE(12),,,,MATC;
Q2      QUE(13),,,,MATC;
Q3      QUE(14),,,,MATC;
Q4      QUE(15),,,,MATC;
Q5      QUE(16),,,,MATC;
Q6      QUE(17),,,,MATC;
Q7      QUE(18),,,,MATC;
Q8      QUE(19),,,,MATC;
Q9      QUE(20),,,,MATC;
Q10     QUE(21),,,,MATC;
MATC    MAT,1,Q1/A1,Q2/A1,Q3/A1,Q4/A1,Q5/A1,Q6/A1,Q7/A1,Q8/A1,
        Q9/A1,Q10/A1;
 A1     ACCUM,10,10,HIGH(3),1;
        COL,INT(1),TOT TIME;
        TERM;
        END;
INIT,0;
FIN;
```

Appendix B

Simulation Model

```
WPS,CM25000,T650,IO150.  T810372,STANBERRY,BOX4577
ATTACH,PROCFIL,SLAMPROC,ID=AFIT.
FTN5,ANSI=0.
BEGIN,SLAM,,M=LGO,PL=10000.
C
C
C
C
      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7)
      DIMENSION NSET (60000)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET (60000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=60000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END
```

```
      SUBROUTINE EVENT (I)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/EVENT4/CTD1,CUTE1,FLYN5,FLYT5,TD1,TODAY,
     +TONN5,TONT5,UTE5,CTD,CTD5,CUTE5,FLYN1,FLYT1,
     +TD,TD5,TONN1,TONT1,UTE1
      GO TO (1,2,3,4,5,6,7,8,9,10,11),I
C
C  EVENT 1:  SETS PARAMETERS FOR W.U.C. # 11
C
C  ** FOR A C-141 **
C
 1    ATRIB(5)=1
      IF(ATRIB(2).EQ.2) GO TO 110
      X1=.0336
      X2=.0604
      Y1=.9954
      Y2=3.0421
      GO TO 100
C
C  ** FOR A C-5 **
C
 110  X1=.373
      X2=.012
      Y1=3.0737
      Y2=.9044
      GO TO 100
C
C  EVENT 2:  SETS PARAMETERS FOR W.U.C. # 13.
C
C  ** FOR A C-141 **
C
 2    ATRIB(5)=2
      IF(ATRIB(2).EQ.2) GO TO 120
      X1=.0317
      X2=.0508
      Y1=.9015
      Y2=1.9368
      GO TO 100
C
C  ** FOR A C-5 **
C
 120  X1=.614
      X2=.035
      Y1=1.2269
      Y2=1.4690
      GO TO 100
C
C  EVENT 3:  SETS PARAMETERS FOR W.U.C. # 14.
C
```

```
C  ** FOR A C-141 **
C
 3    ATRIB(5)=3
      IF(ATRIB(2).EQ.2) GO TO 130
      X1=.0129
      X2=.0278
      Y1=1.0925
      Y2=2.1242
      GO TO 100
C
C  ** FOR A C-5 **
C
 130  X1=.074
      X2=.018
      Y1=1.7996
      Y2=1.5665
      GO TO 100
C
C  EVENT 4:  SETS PARAMETERS FOR W.U.C. # 23.
C
C  ** FOR A C-141 **
C
 4    ATRIB(5)=4
      IF(ATRIB(2).EQ.2) GO TO 140
      X1=.0524
      X2=.0772
      Y1=.7625
      Y2=3.0044
      GO TO 100
C
C  ** FOR A C-5 **
C
 140  X1=.253
      X2=.096
      Y1=1.1153
      Y2=1.6712
      GO TO 100
C
C  EVENT 5:  SETS PARAMETERS FOR W.U.C. # 42.
C
C  ** FOR A C-141 **
C
 5    ATRIB(5)=5
      IF(ATRIB(2).EQ.2) GO TO 150
      X1=.0065
      X2=.0070
      Y1=1.1171
      Y2=1.2157
      GO TO 100
C
```

```
C  ** FOR A C-5 **
C
 150  X1=.119
      X2=.030
      Y1=.3374
      Y2=2.6955
      GO TO 100
C
C  EVENT 6:  SETS PARAMETERS FOR W.U.C. # 45.
C
C  ** FOR A C-141 **
C
 6    ATRIB(5)=6
      IF(ATRIB(2).EQ.2) GO TO 160
      X1=.0097
      X2=.0292
      Y1=.4326
      Y2=4.3023
      GO TO 100
C
C  ** FOR A C-5 **
C
 160  X1=.151
      X2=.248
      Y1=.5574
      Y2=3.6602
      GO TO 100
C
C  EVENT 7:  SETS PARAMETERS FOR W.U.C. # 46.
C
C  ** FOR A C-141 **
C
 7    ATRIB(5)=7
      IF(ATRIB(2).EQ.2) GO TO 170
      X1=.012
      X2=.028
      Y1=1.376
      Y2=2.0044
      GO TO 100
C
C  ** FOR A C-5 **
C
 170  X1=.111
      X2=.012
      Y1=.5229
      Y2=3.5153
      GO TO 100
C
C  EVENT 8:  SETS PARAMETERS FOR W.U.C. # 51.
C
```

```
C  ** FOR A C-141 **
C
 8    ATRIB(5)=8
      IF(ATRIB(2).EQ.2) GO TO 180
      X1=.0218
      X2=.0181
      Y1=.1208
      Y2=9.931
      GO TO 100
C
C  ** FOR A C-5 **
C
 180  X1=.122
      X2=.049
      Y1=.1225
      Y2=13.9255
      GO TO 100
C
C  EVENT 9:  SETS PARAMETERS FOR W.U.C. # 72.
C
C  ** FOR A C-141 **
C
 9    ATRIB(5)=9
      IF(ATRIB(2).EQ.2) GO TO 190
      X1=.0709
      X2=.0266
      Y1=.0439
      Y2=29.5124
      GO TO 100
C
C  ** FOR A C-5 **
C
 190  X1=.262
      X2=.085
      Y1=.3622
      Y2=4.8696
      GO TO 100
C
C  EVENT 10:  SETS PARAMETERS FOR W.U.C. # 55 & # 73.
C
C  ** FOR A C-141 **
C
 10   ATRIB(5)=10
      IF(ATRIB(2).EQ.2) GO TO 200
      X1=.0138
      X2=.0120
      Y1=.1114
      Y2=12.5641
      GO TO 100
C
```

```
C  ** FOR A C-5 **
C
 100  X1=.113
      X2=.560
      Y1=.2707
      Y2=7.2708
C
C
C  ADDRESS 100:  FIRST,DETERMINES EXPECTED NUMBER OF FAILURES
C  FOR THE APPROPRIATE WORK UNIT CODE (USING THE PARAMETERS,
C  X1 AND X2, SET ABOVE), FOR THE OUTBOUND SORTIE.
C
 100  XX(10) = X1 + X2 * ATRIB(4)
C
C  USE EXPECTED NUMBER OF FAILURES AS THE MEAN OF A POISSON
C  DISTRIBUTION TO GET THE NUMBER OF FAILURES GENERATED.
C
      X = NPSSN(XX(10),2)
C
C  DETERMINE EXPECTED NUMBER OF FAILURES FOR RETURN SORTIE.
C
      XX(10) = X1 + X2 * ATRIB(6)
C
C  DETERMINE NUMBER OF FAILURES ON RETURN SORTIE AND ADD
C  TO THE NUMBER OF FAILURES ON THE OUTBOUND SORTIE.
C
      X = X + NPSSN(XX(10),2)
C
C  IF NO FAILURES OCCUR, BOTH MX AND SUPPLY TIMES ARE ZERO.
C
      IF(X.EQ.0) THEN
        ATRIB(3)=0
        ATRIB(4)=0
        RETURN
      ENDIF
C
C  IF FAILURES OCCURED, DETERMINE TIME TO REPAIR (USING
C  PARAMETERS, Y1 AND Y2, SET PREVIOUSLY).  ALL TIMES COME
C  FROM GAMMA DISTRIBUTIONS.
C
      IF(X.GT.0) Y=GAMA(Y1,Y2,3)
C
C  ADJUST MX TIME IF MORE THAN ONE PART FAILED IN THIS SUBSYSTEM.
C
      IF(X.EQ.1) ATRIB(3)=Y
      IF(X.EQ.2) ATRIB(3)=1.5*Y
      IF(X.EQ.3) ATRIB(3)=1.75*Y
      IF(X.GE.4) ATRIB(3)=2.0*Y
C
C  DETERMINE SUPPLY DELAY, IF ANY, IN USERF(6).
```

```
C
      ATRIB(4) = USERF(6)
C
C IF THERE WILL BE A SUPPLY DELAY, DIVIDE MX TIME IN HALF.
C HALF OF THE WORK WILL BE DONE BEFORE, AND HALF AFTER, THE
C SUPPLY DELAY.
C
      IF(ATRIB(4).GT.0) ATRIB(3)=ATRIB(3)/2
      RETURN
C
C
C EVENT 11. THIS EVENT CALCULATES AND PRINTS DAILY UTE
C          RATES, CUMULATIVE UTE RATES, DAILY TONS/DAY,
C          CUMULATIVE TONS/DAY, AND TOTAL TONNAGE ON A
C          DAILY BASIS.
C                 ---N1 = CURRENT C141 FLY TIME/TONNAGE
C                 ---T1 = YESTERDAY'S C141 FLY TIME/TONNAGE
C                 ---N5 = CURRENT C5 FLY TIME/TONNAGE
C                 ---T5 = YESTERDAY'S C5 FLY TIME/TONNAGE
C                   UTE = UTILIZATION (HRS/ACFT/DAY)
C                    TD = TONS/DAY
C
 11   IF (TNOW.NE.24.) GO TO 40
      FLYN1=0
      TONN1=0
      FLYN5=0
      TONN5=0
 40   TODAY=TNOW/24.
      FLYT1=FLYN1
      FLYN1=XX(6)
      UTE1=(FLYN1-FLYT1)/176.
      CUTE1=FLYN1/176./TODAY
      TONT1=TONN1
      TONN1=XX(8)
      TD1=TONN1-TONT1
      CTD1=TONN1/TODAY
C
      FLYT5=FLYN5
      FLYN5=XX(7)
      UTE5=(FLYN5-FLYT5)/53.
      CUTE5=FLYN5/53./TODAY
      TONT5=TONN5
      TONN5=XX(9)
      TD5=TONN5-TONT5
      CTD5=TONN5/TODAY
C
      TOTAL=XX(8)+XX(9)
      TD=TD1+TD5
      CTD=CTD1+CTD5
 401  FORMAT (/," DAY ",F3.0,33X,"C141",7X,"C5")
```

```
402  FORMAT (7X,"UTE PAST 24 HRS",12X,"!",5X,F5.2,5X,F5.2)
403  FORMAT (7X,"CUMULATIVE UTE",13X,"!     ",F5.2,5X,F5.2)
404  FORMAT (7X,"TON/DAY PAST 24 HRS",8X,"!     ",F5.0,5X,F5.0)
405  FORMAT (7X,"CUMULATIVE TONS/DAY",8X,"!     ",F5.0,5X,F5.0)
406  FORMAT (7X,"TOTAL TONS/DAY PAST 24 HRS !",13X,F5.0)
407  FORMAT (7X,"TOTAL CUMULATIVE TONS/DAY  !",13X,F5.0)
408  FORMAT (7X,"TOTAL TONS DELIVERED",7X,"!",3X,F7.0)
     PRINT 401,TODAY
     PRINT 402,UTE1,UTE5
     PRINT 403,CUTE1,CUTE5
     PRINT 404,TD1,TD5
     PRINT 405,CTD1,CTD5
     PRINT 406,TD
     PRINT 407,CTD
     PRINT 408,TOTAL
     RETURN
     END
```

```
      FUNCTION USERF (I)
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      GO TO (1,2,3,4,5,6),I
C
C** DETERMINE ABORT MAINTENANCE TIME **
C
 1    USERF=DRAND(1) + .5
      RETURN
C
C** DETERMINE OFFLOAD TIMES FOR C141 **
C
 2    IF (ATRIB(2).EQ.2) GO TO 22
      IF (DRAND(1).LE..732) GO TO 21
C ** OFFLOAD TIME FOR C141 BULK CARGO **
      USERF = RNORM (1.0,.2,1)
      RETURN
C ** OFFLOAD TIME FOR C141 OVERSIZE CARGO **
 21   USERF = RNORM (.84,.2,1)
      RETURN
C
C ** DETERMINE OFFLOAD TIMES FOR C5 **
C
 22   X = DRAND(1)
      IF (X.LE..615) GO TO 23
      IF (X.LE..775) GO TO 24
C ** OFFLOAD TIME FOR C5 BULK CARGO **
      USERF = RNORM (3.0,.5,1)
      RETURN
C ** OFFLOAD TIME FOR C5 OVERSIZE CARGO **
 23   USERF = RNORM (2.44,.9,1)
      IF (USERF.LT..7.OR.USERF.GT.5.8) GO TO 23
      RETURN
C ** OFFLOAD TIME FOR C5 OUTSIZE CARGO **
 24   USERF = RNORM (2.3,.9,1)
      IF (USERF.LT..5.OR.USERF.GT.6.0) GO TO 24
      RETURN
C
C ** DETERMINE CARGO WEIGHT IN TONS **
C
 3    IF (ATRIB(2).EQ.1) GO TO 31
C ** FOR THE C5 **
      X=DRAND(5)
      IF (X.LE..500) GO TO 41
      IF (X.LE..923) GO TO 42
      GO TO 43
 41   X=DRAND(6)
      IF (X.LE..1111) GO TO 411
      IF (X.LE..1715) GO TO 412
      IF (X.LE..1783) GO TO 413
```

```
      GO TO 414
42    X=DRAND(7)
      IF (X.LE..2302) GO TO 421
      IF (X.LE..3708) GO TO 422
      IF (X.LE..5216) GO TO 423
      IF (X.LE..6172) GO TO 424
      IF (X.LE..6549) GO TO 425
      IF (X.LE..7221) GO TO 426
      GO TO 427
43    X=DRAND(8)
      IF (X.LE..20) GO TO 431
      IF (X.LE..80) GO TO 432
      GO TO 433
411   USERF = 414.04*(X)+14.5
      RETURN
412   USERF = 82.78*(X-.1111)+89.5
      RETURN
413   USERF = 735.29*(X-.1715)+94.5
      RETURN
414   USERF = 3.04*(X-.1783)+99.5
      RETURN
421   USERF = 62.99*(X)+14.5
      RETURN
422   USERF = 106.69*(X-.2302)+29.0
      RETURN
423   USERF = 132.63*(X-.3708)+44.0
      RETURN
424   USERF = 52.3*(X-.5216)+64.0
      RETURN
425   USERF = 530.5*(X-.6172)+74.0
      RETURN
426   USERF = 74.4*(X-.6549)+94.0
      RETURN
427   USERF = 10.8*(X-.7221)+99.0
      RETURN
431   USERF = 175.0*(X)+25.0
      RETURN
432   USERF = 50.0*(X-.20)+60.0
      RETURN
433   USERF = 60.0*(X-.80)+90.0
      RETURN
C ** FOR THE C141 **
31    X=DRAND(5)
      IF (X.LE..500) GO TO 51
      IF (X.LE..692) GO TO 52
      IF (X.LE..923) GO TO 53
      GO TO 54
51    X=DRAND(6)
      IF (X.LE..040) GO TO 511
      IF (X.LE..2166) GO TO 512
```

```
      IF (X.LE..2682) GO TO 513
      IF (X.LE..4765) GO TO 514
      IF (X.LE..6135) GO TO 515
      IF (X.LE..6938) GO TO 516
      GO TO 517
52    X=DRAND(7)
      IF (X.LE..095) GO TO 521
      IF (X.LE..265) GO TO 522
      IF (X.LE..266) GO TO 523
      IF (X.LE..555) GO TO 524
      IF (X.LE..565) GO TO 525
      IF (X.LE..890) GO TO 526
      GO TO 527
53    X=DRAND(8)
      IF (X.LE..1125) GO TO 531
      IF (X.LE..205) GO TO 532
      IF (X.LE..415) GO TO 533
      IF (X.LE..470) GO TO 534
      IF (X.LE..785) GO TO 535
      IF (X.LE..795) GO TO 536
      IF (X.LE..920) GO TO 537
      GO TO 538
54    X=DRAND(9)
      IF (X.LE..210) GO TO 541
      IF (X.LE..460) GO TO 542
      IF (X.LE..750) GO TO 543
      IF (X.LE..875) GO TO 544
      GO TO 545
511   USERF = 125.0*(X)+6.0
      RETURN
512   USERF = 16.99*(X-.04)+11.0
      RETURN
513   USERF = 58.14*(X-.2166)+14.0
      RETURN
514   USERF = 33.16*(X-.2682)+17.0
      RETURN
515   USERF = 72.99*(X-.4765)+24.0
      RETURN
516   USERF = 24.91*(X-.6135)+34.0
      RETURN
517   USERF = 13.06*(X-.6938)+36.0
      RETURN
521   USERF = 52.63*(X)+6.0
      RETURN
522   USERF = 17.65*(X-.095)+11.0
      RETURN
523   USERF = 2000*(X-.265)+14.0
      RETURN
524   USERF = 27.68*(X-.266)+16.0
      RETURN
```

```
525  USERF = 100.*(X-.555)-24.0
     RETURN
526  USERF = 6.15*(X-.555)+34.0
     RETURN
527  USERF = 36.36*(X-.890)+36.0
     RETURN
531  USERF = 35.56*(X)-2.0
     RETURN
532  USERF = 54.05*(X-.1125)+6.0
     RETURN
533  USERF = 14.29*(X-.205)+11.0
     RETURN
534  USERF = 90.91*(X-.415)+14.0
     RETURN
535  USERF = 15.87*(X-.470)+19.0
     RETURN
536  USERF = 1000*(X-.785)+24.0
     RETURN
537  USERF = 16.00*(X-.795)+34.0
     RETURN
538  USERF = 50.00*(X-.920)+36.0
     RETURN
541  USERF = 19.05*(X)+9.0
     RETURN
542  USERF = 8.09*(X-.210)+13.0
     RETURN
543  USERF = 34.45*(X-.460)+15.0
     RETURN
544  USERF = 16.0*(X-.750)+25.0
     RETURN
545  USERF = 32.0*(X-.875)+27.0
     RETURN
C
C ** DETERMINE C141 TURNAROUND TIME **
C
C
C ** USERF(4) = POSTFLIGHT + REFUELING + MX PREFLIGHT
C
 4    USERF = RNORM(.7,.08,4)+UNFRM(1.5,2.5,4)+RNORM(.7,.08,4)
      RETURN
C
C ** DETERMINE C5 TURNAROUND TIME **
C
C
C ** USERF(5) = POSTFLIGHT + REFUELING + MX PREFLIGHT
C
 5    USERF=RNORM(1.5,.12,5)+UNFRM(2.0,4.0,5)+RNORM(1.5,.12,5)
      RETURN
C*********************************************************
C  THIS FUNCTION IS USED TO DETERMINE HOW LONG AN ACFT  **
```

```
C  IS DOWN WHILE WAITING FOR SUPPLY.  NOTE THAT SUPPLY  **
C  IS NOT A FACTOR FOR THE FIRST 12 DAYS (288 HOURS)     **
C  THIS IS DUE TO LOCAL STOCK AND WRSK STOCKPILES.       **
C*********************************************************
C
C** FIRST, DETERMINE IF SUPPLY IS A FACTOR **
C
 6    IF (DRAND(3).LE..95) GO TO 300
      IF (TNOW.LE.288) GO TO 303
C
C** FOR THE C141 **
C
      IF (ATRIB(2).EQ.2) GO TO 30
      X=DRAND(3)
      IF (X.LE..004) GO TO 301
      IF (X.LE..330) GO TO 302
      GO TO 303
 300  USERF=0
      RETURN
 301  USERF=(6000.*(X)+24.)*1.0
      RETURN
 302  USERF=(73.62*(X-.004)+48.)*1.0
      RETURN
 303  USERF=(143.28*(X-.330)+72.)*1.0
      RETURN
C
C** FOR THE C5 **
C
 30   X=DRAND(3)
      IF (X.LE..002) GO TO 304
      IF (X.LE..233) GO TO 305
      IF (X.LE..323) GO TO 306
      IF (X.LE..338) GO TO 307
      IF (X.LE..585) GO TO 308
      GO TO 309
 304  USERF=(12000.*(X)+24.)*1.0
      RETURN
 305  USERF=(103.9*(X-.002)+48.)*1.0
      RETURN
 306  USERF=(266.67*(X-.233)+72.)*1.0
      RETURN
 307  USERF=(1600.*(X-.323)+96.)*1.0
      RETURN
 308  USERF=(97.17*(X-.338)+120.)*1.0
      RETURN
 309  USERF=(57.83*(X-.585)+144.)*1.0
      RETURN
      END
```

```
;TWO BASE CONCEPT OF STRATEGIC AIRLIFT: U.S. TO EUROPE
;
GEN,STANBERRY,HK THESIS,11/29/1981;
LIM,31,6,5000;
TIMST,XX(1),C141 WOUT LE;
TIMST,XX(2),C141 WITH LE;
TIMST,XX(3),C5 WITH LE;
TIMST,XX(4),C5 WOUT LE;
TIMST,XX(5),NUMBER LE FREED;
TIMST,XX(6),C141 FLY TIME;
TIMST,XX(7),C5 FLY TIME;
TIMST,XX(8),C141 TONNAGE;
TIMST,XX(9),C5 TONNAGE;
NETWORK;
     RES/C141(176),1;      C141 AIRCRAFT
     RES/C5(53),2;         C5 AIRCRAFT
     RES/LEUS(28),3;       LOAD EQUIP IN U.S.
     RES/LPUS(70),4;       LOAD PERSONNEL IN U.S.
     RES/AC1U(352),5;      C141 AIRCREWS IN U.S.
     RES/AC5U(86),6;       C5 AIRCREWS IN U.S.
     RES/LEEUR(28),7;       LOAD EQUIP IN EUROPE
     RES/LPEUR(70),8;       LOAD PERSONNEL IN EUROPE
     RES/AC1E(352),9;       C141 AIRCREWS IN EUROPE
     RES/AC5E(86),10;       C5 AIRCREWS IN EUROPE
     RES/M431R2(74),11;       FLT CONTROLS MX PERS
     RES/M431W2(18),12;       LANDING GEAR MX PERS
     RES/M423X0(43),13;       ELECTRICAL SYSTEMS MX PERS
     RES/M423X4(57),14;       PNEUDRAULICS MX PERS
     RES/M426X2(193),15;      ENGINE MX PERS
     RES/M423X1(46),16;       ENVIRONMENTAL SYSTEMS MX PERS
     RES/M423X3(28),17;       FUEL SYSTEMS MX PERS
     RES/M325X1(45),18;       INSTRUMENTS MX PERS
     RES/M325X0(37),19;       AUTOPILOT MX PERS
     RES/M328X1(49),20;       NAVIGATION SYSTEMS MX PERS
     RES/M328X4(36),21;       INS & RADAR MX PERS
;
;INITIALIZE THE MODEL FOR USER FORMATTED DATA
;
     CRE,24,24;
     ACT,,,EV11;
EV11 EVE,11;
     TERM;
;
;CREATE A NEW LOAD EVERY 6 MINUTES
;
     CRE,.10,,1;
     ACT,,NNQ(1).LT.1,AS1;
     ACT,,NNQ(2).LT.1,AS2;
AS1  ASS,ATRIB(2)=1,ATRIB(1)=ATRIB(1)+.01;
     ACT,,,A141;
```

```
;
;WAIT FOR A C141.  41.4% WILL REQUIRE LOAD EQUIPMENT
;
AC1U  AWA(1),C141/1,1;
      ACT,,.586,AS3;
      ACT,,.414,AS4;
AS3   ASS,ATRIB(3)=Ø,ATRIB(4)=RNORM(1.3,.2),XX(1)=XX(1)+1;
      ACT,,,ALP;
AS4   ASS,ATRIB(3)=.1,ATRIB(4)=RNORM(1.3,.2),XX(2)=XX(2)+1;
      ACT,,,ALE;
AS2   ASS,ATRIB(2)=2,ATRIB(1)=ATRIB(1)+.Ø2;
      ACT,,1,AC5;
;
;WAIT FOR A C5.  65.2% WILL REQUIRE LOAD EQUIPMENT
;
AC5   AWA(2),C5/1,1;
      ACT,,.652,AS5;
      ACT,,.348,AS6;
AS5   ASS,ATRIB(3)=.1,ATRIB(4)=RNORM(3.5,.6),XX(3)=XX(3)+1;
      ACT,,,ALE;
AS6   ASS,ATRIB(3)=Ø,ATRIB(4)=RNORM(3.5,.6),XX(4)=XX(4)+1;
      ACT,,,ALP;
;
;WAIT FOR LOAD EQUIP
;
ALE   AWA(3),LEUS/1,1;
      ACT,,,ALP;
;
;WAIT FOR LOAD CREW
;
ALP   AWA(4),LPUS/1,1;
;
;ACCOUNT FOR LOADING TIME.  ATRIB(4) IS LOADING TIME, ATRIB(3)
;IS THE TIME IT TAKES THE LE TO GET TO THE ACFT.
;AFTER FREEING LE AND LP, ACFT ARE READY WITH CARGO AND NEED CREWS.
;
      ACT,ATRIB(3)+ATRIB(4);
      GOO,1;
      ACT,,ATRIB(3).NE.Ø,FLE;
      ACT,,ATRIB(3).EQ.Ø,FLP;
FLE   FRE,LEUS/1;
      ASS,XX(5)=XX(5)+1;
FLP   FRE,LPUS/1,1;
      ACT,,ATRIB(2).EQ.1,C1RC;
      ACT,,,C2RC;
C1RC  COL,INT(1),C141 CARGO READY;
      ACT,,,AC1U;
C2RC  COL,INT(1),C5 CARGO READY;
      ACT,,,AC5U;
;
```

```
;WAIT FOR C141 AIRCREWS
;
AC1U  AWA(5),AC1U/1;
      ACT,,,AS7;
;
;WAIT FOR C5 AIRCREWS
;
AC5U  AWA(6),AC5U/1;
      ACT,,,AS7;
;
;START CREW DUTY DAY 2 HOURS BEFORE REPORT TO AIRCRAFT.  THIS
;ACCOUNTS FOR CREW ASSEMBLY, BRIEFING, ETC.
;
AS7   ASS,ATRIB(5)=TNOW-2.Ø;
      ACT,UNFRM(1.Ø,1.5);
      GOON,1;
;
;15% OF THE AIRCRAFT WILL REQUIRE PRE-TAKEOFF MAINTENANCE.
;TIME DELAYED = USERF(1)
;
      ACT,,.85,AS8;
      ACT,USERF(1),.15,AS8;
;
;FLIGHT TIME TO EUROPE.
;
;
AS8   ASS,ATRIB(4)=RNORM(7.7,.2);
      ACT,ATRIB(4),,GO2;
GO2   GOON,2;
;
;THESE TWO STATEMENTS FOLLOW THE AIRCRAFT FOR UNLOADING,TURNAROUND,
;AND FLIGHT BACK TO THE U.S. (SEE "AIRCRAFT ROUTINE IN EUROPE")
;
      ACT,,ATRIB(3).EQ..1,ALEE;
      ACT,,ATRIB(3).EQ.Ø,ALPE;
;
;THESE TWO STATEMENTS FOLLOW THE AIRCREW AFTER LANDING.  CREWS
;GO THRU DEBRIEFING, ETC., THEN ARE ALLOWED 12 HOURS CREWREST
;BEFORE BEING MAKE AVAILABLE AGAIN.
;
      ACT,UNFRM(1.Ø,1.5),ATRIB(2).EQ.1,CO1;
      ACT,UNFRM(1.Ø,1.5),ATRIB(2).EQ.2,CO2;
CO1   COL,INT(5),C141 DUTY DAY;
      ASS,XX(6)=XX(6)+ATRIB(4),XX(8)=XX(8)+USERF(3);
      ACT,12.Ø;
      FRE,AC1E/1;
      TERM;
CO2   COL,INT(5),C5 DUTY DAY;
      ASS,XX(7)=XX(7)+ATRIB(4),XX(9)=XX(9)+USERF(3);
      ACT,12.Ø;
```

```
      FRE,ACEE/1;
      TERM;
;
;AIRCRAFT ROUTINE IN EUROPE:
;
ALEE  AWA(7),LEEUR/1;
      ACT,,,ALPE;
ALPE  AWA(8),LPEUR/1;
;
;UNLOAD THE ACFT
;
      ACT,USERF(2),,G07;
G07   GOON,1;
      ACT,,ATRIB(3).EQ.1,FLEE;
      ACT,,ATRIB(3).EQ.0,FLPE;
FLEE  FRE,LEEUR/1;
      ACT,,,FLPE;
FLPE  FRE,LPEUR/1;
      COL,INT(1),TRANSIT TIME;
;
;AFTER THE ACFT ARE UNLOADED, SEPARATE THE C141S FROM THE C5S
;AND PREPARE FOR THE RETURN TRIP.
;
      ACT,,ATRIB(2).EQ.1,G05;
      ACT,,ATRIB(2).EQ.2,G06;
G05   GOON,1;  ******************************************************
;
;THIS ACTIVITY INCLUDES POSTFLIGHT, REFUELING, AND MX PREFLT OF C-141S
;
      ACT,UNFRM(2.0,4.0);
;
;NOW WAIT FOR A C141 AIRCREW
;
      AWA(9),AC1E/1,1;
;
;AGAIN, 15% OF THE C141S REQUIRE SOME PRE-TAKEOFF MAINTENANCE.
;
      ACT,UNFRM(.5,1.5),.15,AS10;
      ACT,,.85,AS10;
AS10  ASS,ATRIB(6)=RNORM(9.3,.2),XX(6)=XX(6)+ATRIB(6),1;
;
;FLIGHT BACK TO THE U.S.
;
      ACT,ATRIB(6);
;
;AFTER 13.5 HOURS, CREWS ARE MADE AVAILABLE FOR US-TO-EUROPE
;FLIGHTS.  THIS INCLUDES 12 HOURS FOR CREWREST.
;
      GOON,2;
      ACT,13.5,,FA1U;
```

```
     ACT,,,GO3;
FA1U FRE,AC1U/1;
     TERM;
GO6  GOO,1; ****************************************************
;
;THIS ACTIVITY INCLUDES POSTFLIGHT, REFUELING, AND MX PREFLIGHT OF C5S
;
     ACT,UNFRM(2.0,4.0);
;
;NOW WAIT FOR A C5 AIRCREW.
;
     AWA(10),AC5E/1,1;
;
;HERE, 30% OF THE C5S REQUIRE SOME PRE-TAKEOFF MAINTENANCE.
;
     ACT,UNFRM(.5,1.5),.3,AS11;
     ACT,,.7,AS11;
AS11 ASS,ATRIB(6)=RNORM(9.3,.2),XX(7)=XX(7)+ATRIB(6),1;
;
;FLIGHT BACK TO THE U.S.
;
     ACT,ATRIB(6);
;
;AFTER 13.5 HOURS, CREWS ARE MADE AVAILABLE FOR US-TO-EUROPE
;FLIGHTS.  THIS INCLUDES 12 HOURS FOR CREWREST.
;
     GOO,2;
     ACT,13.5,,FA5U;
     ACT,,,GO3;
FA5U FRE,AC5U/1;
     TERM;
;
;**************************************************************
;*                                                            *
;*  HERE, THE AIRCRAFT ENTERS MAINTENANCE FOR REPAIR AS FOLLOWS:  *
;*                                                            *
;**************************************************************
;
;  AIRCRAFT BRANCHES TO 10 SUBSYSTEM NETWORKS.
;
GO3  GOON,10;
     ACT,,,EV1;
     ACT,,,EV2;
     ACT,,,EV3;
     ACT,,,EV4;
     ACT,,,EV5;
     ACT,,,EV6;
     ACT,,,EV7;
     ACT,,,EV8;
     ACT,,,EV9;
```

```
     ACT,,,EV10;
;
; THIS NETWORK FOLLOWS THE AIRFRAME SUBSYSTEM, W.U.C. 11.
;
; EVENT 1 DETERMINES IF THERE ARE ANY FAILURES IN THIS SUBSYSTEM
; AND SETS MAINTENANCE TIME IN ATTRIBUTE 3 AND SUPPLY DELAY TIME
; IN ATTRIBUTE 4.
;
EV1  EVE,1,1;
;
; IF THERE WERE NO FAILURES, SO NO MAINTENANCE TIME, THE
; SUBSYSTEM GOES DIRECTLY TO WAIT IN QUEUE 1.
;
     ACT,,ATRIB(3).EQ.0,Q1;
;
; IF THERE WERE FAILURES AND THE AIRCRAFT IS A C-141,
; THE SUBSYSTEM BRANCHES TO GOON NODE, G2.
;
     ACT,,ATRIB(2).EQ.1,G2;
;
; IF THERE WERE FAILURES AND THE AIRCRAFT IS A C-5,
; THE SUBSYSTEM BRANCHES TO GOON NODE, G3.
;
     ACT,,ATRIB(2).EQ.2,G2;
;
; FROM G2, THE SUBSYSTEM TAKES ONLY ONE OF THE FOLLOWING BRANCHES.
; THE FIRST ACTIVITY ALWAYS REPRESENTS THE CASE WHERE A TYPE OF
; MAINTENANCE SPECIALTY NOT IN THE MODEL IS REQUIRED.  THERE ARE
; NO RESOURCES ASSIGNED, BUT MAINTENANCE TIME IS ACCOUNTED FOR ON
; THE WAY TO G22.  ALL OTHER BRANCHES REPRESENT THE PROBABILITIES
; OF NEEDING DIFFERENT SPECIALTIES THAT HAVE BEEN MODELED.  IF
; ONE OF THESE IS CHOSEN, THE SUBSYSTEM GOES TO THE APPROPRIATE
; AWAIT NODE TO WAIT FOR MAINTENANCE PERSONNEL.
;
 G2  GOON,1;
     ACT,ATRIB(3),.613,G22;
     ACT,,.303,AW1;
     ACT,,.084,AW4;
;
; FROM G3,  AGAIN ONLY ONE BRANCH IS TAKEN, BUT THESE CHOICES
; REPRESENT THE RESOURCES REQUIRED BY A C-5 FOR THIS SUBSYSTEM.
;
G3   GOON,1;
     ACT,ATRIB(3),.453,G22;
     ACT,,.264,AW1;
     ACT,,.051,AW3;
     ACT,,.232,AW4;
;
; THIS NETWORK FOLLOWS THE LANDING GEAR SUBSYSTEM,
; W.U.C. 13, IN THE SAME PATTERN AS ABOVE.
```

```
;
EV2   EVE,2,1;
      ACT,,ATRIB(3).EQ.0,G2;
      ACT,,ATRIB(2).EQ.1,G4;
      ACT,,ATRIB(2).EQ.2,G5;
G4    GOON,1;
      ACT,ATRIB(3),.08,G22;
      ACT,,.473,AW2;
      ACT,,.145,AW3;
      ACT,,.302,AW4;
G5    GOON,1;
      ACT,ATRIB(3),.128,G22;
      ACT,,.047,AW1;
      ACT,,.472,AW2;
      ACT,,.078,AW3;
      ACT,,.201,AW4;
      ACT,,.074,AW8;
EV3   EVE,3,1;
;
; THIS NETWORK FOLLOWS THE FLIGHT CONTROLS SUBSYSTEM,
; W.U.C. 14, IN THE SAME PATTERN AS ABOVE.
;
      ACT,,ATRIB(3).EQ.0,G2;
      ACT,,ATRIB(2).EQ.1,G6;
      ACT,,ATRIB(2).EQ.2,G7;
G6    GOON,1;
      ACT,ATRIB(3),.189,G22;
      ACT,,.254,AW1;
      ACT,,.105,AW3;
      ACT,,.228,AW4;
      ACT,,.156,AW8;
      ACT,,.068,AW9;
G7    GOON,1;
      ACT,ATRIB(3),.217,G22;
      ACT,,.163,AW1;
      ACT,,.127,AW3;
      ACT,,.493,AW4;
;
; THIS NETWORK FOLLOWS THE ENGINE SUBSYSTEM, W.U.C. 23,
; IN THE SAME PATTERN AS ABOVE.
;
EV4   EVE,4,1;
      ACT,,ATRIB(3).EQ.0,G4;
      ACT,,ATRIB(2).EQ.1,G8;
      ACT,,ATRIB(2).EQ.2,G9;
G8    GOON,1;
      ACT,ATRIB(3),.177,G22;
      ACT,,.434,AW5;
      ACT,,.389,AW8;
G9    GOON,1;
```

```
     ACT,ATRIB(3),.257,G22;
     ACT,,.411,AW5;
     ACT,,.33Ø,AW8;
;
;  THIS NETWORK FOLLOWS THE ELECTRICAL SUBSYSTEM, W.U.C. 42,
;  IN THE SAME PATTERN AS ABOVE.
;
EV5  EVE,5,1;
     ACT,,ATRIB(3).EQ.Ø,Q5;
     ACT,,ATRIB(2).EQ.1,G1Ø;
     ACT,,ATRIB(2).EQ.2,G11;
G1Ø  GOON,1;
     ACT,ATRIB(3),.113,G22;
     ACT,,.Ø78,AW1;
     ACT,,.7Ø7,AW3;
     ACT,,.Ø51,AW5;
     ACT,,.Ø51,AW9;
G11  GOON,1;
     ACT,ATRIB(3),.235,G22;
     ACT,,.576,AW3;
     ACT,,.189,AW5;
;
;  THIS NETWORK FOLLOWS THE PNEUDRAULICS SUBSYSTEM, W.U.C. 45,
;  IN THE SAME PATTERN AS ABOVE.
;
EV6  EVE,6,1;
     ACT,,ATRIB(3).EQ.Ø,Q6;
     ACT,,ATRIB(2).EQ.1,G12;
     ACT,,ATRIB(2).EQ.2,G13;
G12  GOON,1;
     ACT,ATRIB(3),.Ø23,G22;
     ACT,,.912,AW4;
     ACT,,.Ø65,AW8;
G13  GOON,1;
     ACT,ATRIB(3),.Ø82,G22;
     ACT,,.72Ø,AW4;
     ACT,,.146,AW6;
     ACT,,.Ø52,AW8;
;
;  THIS NETWORK FOLLOWS THE FUEL SUBSYSTEM, W.U.C. 46,
;  IN THE SAME PATTERN AS ABOVE.
;
EV7  EVE,7,1;
     ACT,,ATRIB(3).EQ.Ø,Q7;
     ACT,,ATRIB(2).EQ.1,G14;
     ACT,,ATRIB(2).EQ.2,G15;
G14  GOON,1;
     ACT,ATRIB(3),.Ø68,G22;
     ACT,,.54Ø,AW7;
     ACT,,.392,AW8;
```

```
G15   GOON,1;
      ACT,ATRIB(3),.Ø97,G22;
      ACT,,.416,AW3;
      ACT,,.2Ø9,AW7;
      ACT,,.278,AW8;
;
;  THIS NETWORK FOLLOWS THE INSTRUMENTS SUBSYSTEMS, W.U.C. 51,
;  IN THE SAME PATTERN AS ABOVE.
;
EV8   EVE,8,1;
      ACT,,ATRIB(3).EQ.Ø,G8;
      ACT,,ATRIB(2).EQ.1,G16;
      ACT,,ATRIB(2).EQ.2,G17;
G16   GOON,1;
      ACT,ATRIB(3),.ØØ8,G22;
      ACT,,.992,AW8;
G17   GOON,1;
      ACT,ATRIB(3),.Ø77,G22;
      ACT,,.528,AW8;
      ACT,,.277,AW9;
      ACT,,.118,AW12;
;
;  THIS NETWORK FOLLOWS THE RADAR SUBSYSTEM, W.U.C. 72,
;  IN THE SAME PATTERN AS ABOVE.
;
EV9   EVE,9,1;
      ACT,,ATRIB(3).EQ.Ø,G9;
      ACT,,ATRIB(2).EQ.1,G18;
      ACT,,ATRIB(2).EQ.2,G19;
G18   GOON,1;
      ACT,ATRIB(3),.ØØ8,G22;
      ACT,,.992,AW1Ø;
G19   GOON,1;
      ACT,ATRIB(3),.Ø12,G22;
      ACT,,.588,AW1Ø;
      ACT,,.4ØØ,AW11;
;
;  THIS NETWORK FOLLOWS THE MALFUNCTION ANALYSIS SUBSYSTEM,
;  W.U.C. 55 IN THE C-5, OR THE INERTIAL NAVIGATION SUBSYSTEM,
;  W.U.C. 73 IN THE C-141, IN THE SAME PATTERN AS ABOVE.
;
EV1Ø  EVE,1Ø,1;
      ACT,,ATRIB(3).EQ.Ø,G1Ø;
      ACT,,ATRIB(2).EQ.1,G2Ø;
      ACT,,ATRIB(2).EQ.2,G21;
G2Ø   GOON,1;
      ACT,ATRIB(3),.ØØ2,G22;
      ACT,,.567,AW1Ø;
      ACT,,.431,AW11;
G21   GOON,1;
```

```
     ACT,ATRIB(3),.342,G22;
     ACT,,.086,AW5;
     ACT,,.872,AW11;
;
;
; THE NEXT SERIES OF NETWORKS REPRESENT THE ALLOCATION OF THE
; MAINTENANCE SPECIALTIES THAT HAVE BEEN MODELED.  AFTER THE
; MAINTENANCE HAS BEEN DONE AND SUPPLY DELAYS ACCOUNTED FOR,
; ALL OF THESE NETWORKS END AT G22.  THUS, AS ABOVE, ONLY THE
; FIRST WILL BE EXPLAINED IN DETAIL.
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 431R2, THE FLIGHT
; CONTROLS MAINTENANCE PERSONNEL.  THE SUBSYSTEMS WAIT HERE FOR
; PERSONNEL TO BE ASSIGNED
;
AW1  AWA(11),M431R2/1,1;
;
; MAINTENANCE IS ACCOMPLISHED FOR THE TIME IN ATTRIBUTE 3.
;
     ACT,ATRIB(3);
;
; THE MAINTENANCE PERSONNEL ARE FREED.
;
     FRE,M431R2/1,1;
;
; IF THERE IS NO SUPPLY DELAY IN ATTRIBUTE 4, THE SUBSYSTEM
; PROCEEDS TO G22.
;
     ACT,,ATRIB(4).EQ.0,G22;
;
; IF THERE IS A SUPPLY DELAY, WE WAIT FOR SPARE PARTS FOR THE
; AMOUNT OF TIME IN ATTRIBUTE 4, AND THEN SET ATTRIBUTE 4 EQUAL
; TO ZERO SO THE SUBSYSTEM WILL NOT INCUR ANY FURTHER DELAY.
;
     ACT,ATRIB(4),ATRIB(4).GT.0;
     ASS,ATRIB(4)=0;
;
; FROM HERE, THE SUBSYSTEM IS ROUTED BACK TO THE AWAIT NODE
; TO HAVE MAINTENANCE MEN RE-ASSIGNED SO THE REPAIR CAN BE
; COMPLETED WITH THE SPARE PARTS.  NOTE THAT THE REPAIR TIME
; WAS ACTUALLY CUT IN HALF, IN THE EVENT ROUTINE, TO MAKE
; THIS DOUBLE TRIP THROUGH MAINTENANCE POSSIBLE. AFTER THE
; MAINTENANCE IS COMPLETE, SUPPLY DELAY IS ZERO, SO THE
; SUBSYSTEM WILL GO TO G22.
;
     ACT,,,AW1;
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 431W2, THE LANDING
; GEAR MAINTENANCE PERSONNEL, IN THE SAME PATTERN AS ABOVE.
;
```

```
AW2   AWA(12),M431W2/1,1;
      ACT,ATRIB(3);
      FRE,M431W2/1,1;
      ACT,,ATRIB(4).EQ.Ø,G22;
      ACT,ATRIB(4),ATRIB(4).GT.Ø;
      ASS,ATRIB(4)=Ø;
      ACT,,,AW2;
;
;  THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 423XØ, THE
;  ELECTRICAL SYSTEMS MAINTENANCE PERSONNEL, IN THE SAME PATTERN
;  AS ABOVE.
;
AW3   AWA(13),M423XØ/1,1;
      ACT,ATRIB(3);
      FRE,M423XØ/1,1;
      ACT,,ATRIB(4).EQ.Ø,G22;
      ACT,ATRIB(4),ATRIB(4).GT.Ø;
      ASS,ATRIB(4)=Ø;
      ACT,,,AW3;
;
;  THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 423X4, THE
;  PNEUDRAULICS MAINTENANCE PERSONNEL, IN THE SAME PATTERN
;  AS ABOVE.
;
AW4   AWA(14),M423X4/1,1;
      ACT,ATRIB(3);
      FRE,M423X4/1,1;
      ACT,,ATRIB(4).EQ.Ø,G22;
      ACT,ATRIB(4),ATRIB(4).GT.Ø;
      ASS,ATRIB(4)=Ø;
      ACT,,,AW4;
;
;  THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 426X2, THE ENGINE
;  MAINTENANCE PERSONNEL, IN THE SAME PATTERN AS ABOVE.
;
AW5   AWA(15),M426X2/1,1;
      ACT,ATRIB(3);
      FRE,M426X2/1,1;
      ACT,,ATRIB(4).EQ.Ø,G22;
      ACT,ATRIB(4),ATRIB(4).GT.Ø;
      ASS,ATRIB(4)=Ø;
      ACT,,,AW5;
;
;  THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 423X1, THE
;  ENVIRONMENTAL SYSTEMS MAINTENANCE PERSONNEL, IN THE
;  SAME PATTERN AS ABOVE.
;
AW6   AWA(16),M423X1/1,1;
      ACT,ATRIB(3);
      FRE,M423X1/1,1;
```

```
        ACT,,ATRIB(4).EQ.0,G22;
        ACT,ATRIB(4),ATRIB(4).GT.0;
        ASS,ATRIB(4)=0;
        ACT,,,AW6;
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 423X3, THE FUEL
; SYSTEMS MAINTENANCE PERSONNEL, IN THE SAME PATTERN AS ABOVE.
;
AW7     AWA(17),M423X3/1,1;
        ACT,ATRIB(3);
        FRE,M423X3/1,1;
        ACT,,ATRIB(4).EQ.0,G22;
        ACT,ATRIB(4),ATRIB(4).GT.0;
        ASS,ATRIB(4)=0;
        ACT,,,AW7;
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 325X1, THE AVIONIC
; INSTRUMENTS MAINTENANCE PERSONNEL, IN THE PATTERN AS ABOVE.
;
AW8     AWA(18),M325X1/1,1;
        ACT,ATRIB(3);
        FRE,M325X1/1,1;
        ACT,,ATRIB(4).EQ.0,G22;
        ACT,ATRIB(4),ATRIB(4).GT.0;
        ASS,ATRIB(4)=0;
        ACT,,,AW8;
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 325X0, THE
; AUTOMATIC FLIGHT CONTROLS MAINTENANCE PERSONNEL, IN THE
; SAME PATTERN AS ABOVE.
;
AW9     AWA(19),M325X0/1,1;
        ACT,ATRIB(3);
        FRE,M325X0/1,1;
        ACT,,ATRIB(4).EQ.0,G22;
        ACT,ATRIB(4),ATRIB(4).GT.0;
        ASS,ATRIB(4)=0;
        ACT,,,AW9;
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 328X1, THE AVIONIC
; NAVIICATION SYSTEMS MAINTENANCE PERSONNEL, IN THE SAME PATTERN
; AS ABOVE.
;
AW10    AWA(20),M328X1/1,1;
        ACT,ATRIB(3);
        FRE,M328X1/1 1;
        ACT,,ATRIB(4).EQ.0,G22;
        ACT,ATRIB(4),ATRIB(4).GT.0;
        ASS,ATRIB(4)=0;
        ACT,,,AW10;
```

```
;
; THIS NETWORK FOLLOWS THE ASSIGNMENT OF AFSC 328X4, THE INERTIAL
; AND RADAR NAVIGATION SYSTEMS MAINTENANCE PERSONNEL, IN THE SAME
; PATTERN AS ABOVE.
;
AW11  AWA(21),M328X4/1,1;
      ACT,ATRIB(3);
      FRE,M328X4/1,1;
      ACT,,ATRIB(4).EQ.0,G22;
      ACT,ATRIB(4),ATRIB(4).GT.0;
      ASS,ATRIB(4)=0;
      ACT,,,AW11;
;
; NOTE THAT ALL SUBSYSTEMS CONVERGE ON THIS POINT, FROM THE
; NETWORKS THAT MODEL MAINTENANCE PERSONNEL, OR DIRECTLY
; FROM THE BRANCHING NODES AFTER THE EVENTS.
;
G22   GOON,1;
;
; IF THE SUBSYSTEMS THAT CAME FROM THE BRANCHING NODES STILL
; HAVE SUPPLY DELAY TIME IN ATTRIBUTE 4, THAT TIME PLUS THE
; SECOND TIME THROUGH THE MAINTENANCE TIME ARE ACCOUNTED FOR
; ON THE WAY TO G23.
;
      ACT,ATRIB(3)+ATRIB(4),ATRIB(4).GT.0,G23;
;
; ALL OTHERS, WITH ATTRIBUTE 4 EQUAL TO ZERO, PROCEED TO G23
; WITH NO DELAY.
;
      ACT,,ATRIB(4).EQ.0,G23;
;
; FROM THIS NODE, THE SUBSYSTEMS GO TO THE APPROPRIATE QUEUE.
; ATTRIBUTE 5 IS SET, IN EACH EVENT, TO THE NUMBER OF THAT
; EVENT.  THUS, THE CONDITIONAL BRANCHING ENSURES THAT EACH
; SUBSYSTEM WILL WAIT IN THE APPROPRIATE QUEUE.
;
G23   GOON,1;
      ACT,,ATRIB(5).EQ.1,Q1;
      ACT,,ATRIB(5).EQ.2,Q2;
      ACT,,ATRIB(5).EQ.3,Q3;
      ACT,,ATRIB(5).EQ.4,Q4;
      ACT,,ATRIB(5).EQ.5,Q5;
      ACT,,ATRIB(5).EQ.6,Q6;
      ACT,,ATRIB(5).EQ.7,Q7;
      ACT,,ATRIB(5).EQ.8,Q8;
      ACT,,ATRIB(5).EQ.9,Q9;
      ACT,,ATRIB(5).EQ.10,Q10;
;
; THESE TEN QUEUES CORRESPOND TO THE SAME NUMBER EVENTS,
; SO EACH SUBSYSTEM HAS A DISTINCT PLACE TO WAIT FOR
```

```
; COMPLETION OF MAINTENANCE IN ALL TEN SUBSYSTEMS.
;
Q1    QUE(22),,,,MATC;
Q2    QUE(23),,,,MATC;
Q3    QUE(24),,,,MATC;
Q4    QUE(25),,,,MATC;
Q5    QUE(26),,,,MATC;
Q6    QUE(27),,,,MATC;
Q7    QUE(28),,,,MATC;
Q8    QUE(29),,,,MATC;
Q9    QUE(3Ø),,,,MATC;
Q1Ø   QUE(31),,,,MATC;
;
; WHEN ALL TEN SUBSYSTEMS HAVE COMPLETED MAINTENANCE, SHOWN BY
; HAVING AN ENTITY IN EACH OF THE TEN QUEUES WITH THE SAME MARK
; TIME IN ATTRIBUTE 1, THEY ARE MATCHED AND SENT TO A1.
;
MATC  MAT,1,Q1/A1,Q2/A1,Q3/A1,Q4/A1,Q5/A1,Q6/A1,Q7/A1,Q8/A1,Q9/A1,
      Q1Ø/A1;
;
; THE ACCUMULATE NODE COMBINES ALL TEN SUBSYSTEMS INTO ONE
; AIRCRAFT THAT IS READY TO DEPART MAINTENANCE.
;
A1    ACCUM,1Ø,1Ø,HIGH(3),1;
;
;****************************************************************
;*                                                              *
;*       AT THIS POINT, THE AIRCRAFT DEPARTS MAINTENANCE        *
;*                                                              *
;****************************************************************
;
;
;AIRCRAFT TURNAROUND AND RETURN TO ACFT RESOURCE WHERE IT
;WAITS FOR CARGO (SEE BEGINNING OF NETWORK).
;
      ACT,USERF(4),ATRIB(2).EQ.1,F141;
      ACT,USERF(5),ATRIB(2).EQ.2,FC5;
;
;ONCE THE ACFT IS FIXED, IT IS MADE AVAILABLE FOR USE.
;
F141  FRE,C141/1;
      TERM;
FC5   FRE,C5/1;
      TERM;
      END;
INIT,Ø,72Ø;
SEEDS,-12439782291Ø957(1),-3467133363389(2),-79654468614381(3);
SEEDS,-18417Ø232136813(4),-28ØØ33Ø29935Ø85(5),-147959512963949(6);
SEEDS,-125894583854829(7),-15Ø477775663725(8),-227874746727917(9);
SEEDS,-82174Ø77946221(1Ø);
MONTR,SUMRY,24.,24.;
FIN;
```

VITA

Wayne P. Stanberry was born 16 October 1948 in Roswell, New Mexico. He graduated from high school in Murfreesboro, Tennessee in 1966 and enlisted in the United States Air Force. He attended the United States Air Force Academy Preparatory School in 1968 and the United States Air Force Academy, from which he received a Bachelor of Science degree in June 1973. After completing pilot training at Williams AFB, he spent four years as a C-141 pilot at Charleston AFB, South Carolina. In 1978, he transferred to Shepherd AFB, Texas and taught German and Dutch students as a flying training instructor. After completing Squadron Officers School at Maxwell AFB, he entered the School of Engineering, Air Force Institute of Technology, in August 1980.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GST/OS/82M-13	2. GOVT ACCESSION NO. AD-A115 740	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN IMPROVED MAINTENANCE MODEL FOR THE SIMULATION OF STRATEGIC AIRLIFT CAPABILITY		5. TYPE OF REPORT & PERIOD COVERED MS Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wayne P. Stanberry Captain, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT-EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE March 1982
		13. NUMBER OF PAGES 130
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

LYNN E. WOLAVER
Dean for Research and
Professional Development
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AFB, OH 45433

18. SUPPLEMENTARY NOTES

Approved for public release; IAW AFR 190-17

~~F.C. Lynch, Major, USAF~~
~~Director of Information~~

4 JUN 1982

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Strategic Airlift
Simulation Model
Maintenance Manning
Airlift Capability
SLAM

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The subject of this thesis is modeling of the maintenance function in the strategic airlift system. The implicit assumptions of the universal maintenance man concept are investigated for applicability. A more detailed model of the maintenance function is developed using SLAM as the primary simulation language. Maintenance manning is modeled at the Air Force Specialty Code level, to allow the possibility of bottlenecks in manning

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) requirements. Maintenance discrepancies are determined for major subsystems of the airlift aircraft, and distributions for repair times are estimated for each subsystem. Substituting the detailed model of maintenance for a model that uses universal maintenance men, subsequent runs of a simulation of the airlift system show the assumptions of the universal maintenance man concept to be invalid. Additionally, in a simulation using aggregate bases, maintenance manning is not a significant factor.